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Contents

Foreword

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Introduction

This International Standard defines a Land Cover Classification System (LCCS) based on the Land Cover Classification System establsihed by the Food and Agricultural Organization (FAO) of the Untied Nations. This classification system is one particular classification system for land cover and does not excluse other classification systems being established for land cover or for other purposes. This classification system complies with the general structure for classification systems defined in part 1 of this multi-part standard. The structure used to represent the classified data is that of a discrete coverage as described in ISO 19123. The classifiers described within this system are maintained in a register, compliant with ISO 19135, managed by the UN FAO. This document standardizes the general principals and organization of the UN FAO LCCS so that data defined in this classification system can be used in broader applications than those identified by the UN FAO and so that data defined in other classification schemes can be used together with or fused with data described according to this classification scheme. By standardizing the principals and structure of a classification scheme it is possible to interwork with other application areas or other classification systems. This is similar to interworking between other geographic information that complies to the same feature cataloging methodology, although in this case the concept of features are constrained to that of a classification system that partitions the attribute space (range) of a discrete coverage.

Efficient assessment of land cover and the ability to monitor change are fundamental to sustainable management of natural resources, environmental protection, food security and successful humanitarian programmes. Such information is also required by the Food and Agriculture Organization of the United Nations (FAO) in achieving its mandate of raising levels of nutrition, improving agricultural productivity, enhancing the lives of rural populations and contributing to sustainable growth of the world economy. However, in the past, policy-makers and planners have not had access to reliable and comparable land cover data, not only for lower-income countries but also at the regional and global levels. FAO and the United Nations Environment Programme (UNEP) have been collaborating in numerous initiatives for improving the reliability and compatibility of land cover data sets, and enabling access to the information for a large user community.

A recent example of such collaboration is the Global Land Cover Network (GLCN), launched in 2004, with the support of the Government of Italy, the Government of the Netherlands and numerous institutes worldwide. A critical factor in implementing such global activities is the availability of a common, harmonized land cover classification system that provides a reliable basis for interaction among the increasing number of national, regional and global land cover mapping and monitoring activities. In the absence of a generally accepted or applicable system, FAO and UNEP have developed the Land Cover Classification System (LCCS), which enables comparison of land cover classes regardless of mapping scale, land cover type, data collection method or geographic location. LCCS' inherent flexibility, its applicability in all climatic zones and environmental conditions, and the built-in compatibility with other classification systems has given LCCS the potential to be accepted as an international standard since it has broad appicability in all regions of the world.

An earlier version of LCCS was published by the UN FAO in 2000 and LCCS is already widely implemented and an important tool in global mapping, being used in initiatives such as the Global Land Cover 2000 project, and for the next global assessment, GLOBCOVER, which aims to produce a global land cover map for the year 2005. Developed initially through the practical experience of the Africover project, LCCS has been widely adopted at the national level throughout Africa, Asia, Near East and Latin America. The feedback from this large user community has resulted in the improved and updated second version of the LCCS. The second version of the LCCS is fully compatible with the first version. The difference to the system of classifiers consists of minor improvements. The major improvements in the UN FAO LCCS version 2 are with the software made avail;able by the UN FAO to utalize the LCCS.

This standard is derived from the LCCS - Land Cover Classification System specification developed by the Food and Agricultural Organization of the United Nations. - Ref: [26] and Ref: [27].

Geographic information — Classification Systems - Part 2, UN FAO - Land Cover Classification System LCCS

1 Scope

This International Standard specifies the structure for the Land Cover Classification System of the Food and Agricultural Organization of the Untied Nations. The general criteria and structure of the classification system are defined in this standard and the detailed structure of a register of classifiers is identified. The contents and maintenance of this register are not part of this standard, but are maintained by the UN FAO.

2 Conformance

2.1 Introduction

Two conformance classes are identified for this International Standard.

2.2 Conformance of the LCCS classification system

The LCCS classification system defined in this shall satisfy all of the conditions specified in the following Abstract Test Suite:

a) ISO 19xxx-1 for general conformance of the classification system, and

b) Annex A.2 of this International Standard.

2.3 Conformance of the LCCS register of classifiers

The register of classifiers for the LCCS defined in this International Standard shall satisfy all of the conditions specified in the following Abstract Test Suites:

a) ISO 19xxx-1 for the general register structure, and

b) Annex A.3 of this International Standard.

3 Normative references

ISO/IEC 19501:200x—[1], *Information technology — Unified Modeling Language (UML)*

ISO 19103:—, *Geographic information— Conceptual Schema Language*

ISO 191xx-1:—1), *Geographic information — Classification Systems Part 1, Classification system structure*

ISO 19135:—1), *Geographic information — Procedures for registration of items of geographic information*

4 Terms, definitions, and abbreviations

4.1 Terms and definitions

For the purposes of this International Standard, the following terms and definitions apply. The technical terms applying to plant physionomy, and terms from other diciplines used to establish the classifiers in the classification scheme are not defined in this standard. These terms are either defined in the register of classifiers managed by the UN FAO accociated with this standard, or are referenced in the literature for the supporting dicipline. These references are contained in the bibliography.

4.1.1
a posteriori classification
a classification scheme based upon definition of classes after clustering the field samples collected.. [UNFAO LCCS - Ref : [27]]

NOTE The advantage of this type of classification is its flexibility and adaptability compared with the implicit rigidity of an a priori classification.

EXAMPLE An example is the Braun-Blanquet method, used in vegetation science. This is a floristic classification approach using the total species combination to cluster samples in sociological groups.

4.1.2
a priori classification
a classification scheme structured so that the classes are abstract conceptualizations of the types actually occurring.. [UNFAO LCCS - Ref : [27]]

NOTE The approach is based upon definition of classes before any data collection actually takes place. Thus all possible combinations of diagnostic criteria must be dealt with beforehand in the classification.

4.1.3
classification object
A spatial object, temporal object, or spatiotemporal object defined in terms of a set of classifiers [191xx-1]

4.1.4
classification system
a scheme where the range of attribute for a discrete coverage are a set of classifiers [191xx-1]

4.1.5
classifier
definition or rule that may be used in a particular context to partition the attribute space of a discrete coverage to establish a classification object [191xx-1]

Note: Classifiers may be algorithmicly defined, or defined according to a set of classification system specific rules.

4.1.6
classification
abstract representation of the situation in the field using well-defined diagnostic criteria: the classifiers [UNFAO LCCS - Ref : [27]]

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1) To be published.

Note: Sokal (1974) defined it as: “the ordering or arrangement of objects into groups or sets on the basis of their relationships”.

Note: A classification describes the systematic framework with the names of the classes and the criteria used to distinguish them, and the relationship between classes. Classification thus requires the definition of class boundaries, which should be clear, precise, possibly quantitative, and based upon objective criteria.

4.1.8
discrete coverage
coverage that returns the same **feature attribute** values for every **direct position** within any single **spatial object**, temporal object, or **spatiotemporal object** in its **domain** [ISO 19123]

NOTE The domain of a discrete coverage consists of a finite set of spatial, temporal, or spatiotemporal objects.

4.1.12
feature
abstraction of real world phenomena [ISO 19110]

EXAMPLE The phenomenon named “Eiffel Tower” may be classified with other similar phenomena into a feature type named “tower”.

NOTE A feature may occur as a type or an instance. In this International Standard, feature type is meant unless otherwise specified.

4.1.13
feature attribute
characteristic of a **feature** [ISO 19110]

4.1.14
heirarchical classification
a classification scheme structured to further systematic subdivision into more detailed sub-classes. [UNFAO LCCS - Ref : [27]]

NOTE Most systems are hierarchically structured because such a classification offers more consistency owing to its ability to accommodate different levels of information.. At each level the defined classes are mutually exclusive. At the higher levels of the classification system few diagnostic criteria are used, whereas at the lower levels the number of diagnostic criteria increases. Criteria used at one level of the classification should not be repeated at another lower level.

4.1.15
identifier
linguistically independent sequence of characters capable of uniquely and permanently identifying that with which it is associated [ISO 19135]

4.1.16
item class
set of items with common properties [ISO 19135]

NOTE Class is used in this context to refer to a set of instances, not the concept abstracted from that set of instances.

4.1.17
land cover
observed (bio)physical cover on the earth’s surface. [UNFAO LCCS - Ref : [27]]

NOTE Land cover is distinct from land use.

NOTE When considering land cover in a very pure and strict sense, it should be confined to the description of vegetation and man-made features. Consequently, areas where the surface consists of bare rock or bare soil are land itself rather than land cover. Also, it is disputable whether water surfaces are real land cover. However, in practice, the scientific community usually includes these features within the term land cover.

4.1.18
land use
arrangements, activities and inputs people undertake in acertain land cover type to produce, change or maintain it.. [UNFAO LCCS - Ref : [27]]

NOTE Definition of land use in this way establishes a direct link between land cover and the actions of people in their environment..

EXAMPLE "recreation area" is a land use term that may be applicable to different land cover types: for instance sandy surfaces, like a beach; a built-up area like a pleasure park; woodlands; etc..

4.1.9
legend
application of a classification in a specific area using a defined mapping scale and specific data set [UNFAO LCCS - Ref : [27]]

Note: a legend may contain only a proportion, or sub-set, of all possible classes of the classification and is scale and cartographic representation dependent and data and mapping methodology dependent.

4.1.20
range
<coverage>
set of **feature attribute** values associated by a **function** with the elements of the **domain** of a **coverage** [ISO 19123]

4.1.21
register
set of files containing **identifiers** assigned to items with descriptions of the associated items [ISO 19135]

4.1.22
registry
information system on which a **register** is maintained [ISO 19135]

4.2 Abbreviations

AGLS	Soil Resources, Management and Conservation Service, FAO
AVHRR	Advanced Very High Resolution Radiometer
CEC	Commission of the European Communities
CORINE	Coordination of Information on the Environment, EU
DIS	Data and Information System
ECWG	Vegetation Subcommittee and Earth Cover Working Group, USA
FAO	Food and Agriculture Organization of the United Nations
FGDC	Federal Geographic Data Committee, USA
GIS	Geographical Information System
IGBP	International Geosphere-Biosphere Programme
LCC	Land Cover Classification
LCCS	Land Cover Classification System
LGP	Length of Growing Period
LUCC	Land Use and Land Cover Change
NOAA	National Oceanic and Atmospheric Administration, USA

P / P	Precipitation
PET	Potential Evapotranspiration
ppm	parts per million
SCS	Soil Conservation Service, USA
SDRN	Environment and Natural Resources Service, FAO
SOTER	Soils and Terrain [methodology]
T / T	Temperature
TDS	Total Dissolved Solids
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFAO	United Nations Food and Agriculture Organization
USDA	United States Department of Agriculture

5 Context

5.1 Background

The UN FAO LCCS is a comprehensive, a priori classification system designed to meet specific user requirements, and created for mapping exercises, independent of the scale or means used to map. It enables a comparison of land cover classes regardless of data source, thematic discipline or country. The LCCS system enhances the standardization process and minimizes the problem of dealing with a very large amount of pre-defined classes.

To facilitate the complex classification process and ensure standardization, support software has been developed to guide the user to select the appropriate class. This support software is available form the UN FAO; The software is not part of the standard, but is available to support the use of the standard. The new version of the LCCS software accompaning version 2 of the UN specification is fully compatible with the previous version to ensure continuity of past and future LCCS mapping activities

LCCS has been developed on the experience gained from numerous FAO/UNEP and country mapping activities. The first full operational version of the Land Cover Classification System (LCCS) was developed for the implementation of the Africover - East Africa Project, which was supported by the Government of in collaboration with the Environment and Natural Resources Service (SDRN) and the Soil Resources, Management and Conservation Service (AGLS) of FAO. These land cover classification concepts were discussed and endorsed at the meeting of the International Working Group on Classification and Legend (Senegal, July 1996) supported by Government of France. The second version of the LCCS was developed through an interactive feedback approach involving a large global community, as well as from the experience gained through the implementation of the Africover and other projects. Many institutions and individuals have provided input. Particular input has been received from the U.S. Federal Geographic Data Committee - Vegetation Sub-committee and Earth Cover Working Group, Washington, and the USDA Forest Service, and the the LANES concerted action funded under the 4th Framework Programme of Research on Environment and Climate of the European Commission, as well as the input and support of many academic institutions.

5.2 Overview

The Land Cover Classification System (LCCS) makes use of the general structure for classifications systems defined in part 1 of this standard. It is an a priori classification system based on plant physionomy. The system can be used for any land cover classification initiative anywhere in the world, using a set of independent diagnostic criteria that allow correlation with existing classifications and legends.

Land cover classes are defined by a combination of a set of independent diagnostic criteria – the classifiers – that are hierarchically arranged to assure a high degree of geographical accuracy. Due to the heterogeneity of land cover, the same set of classifiers cannot be used to define all land cover types. The hierarchical structure of the classifiers may differ from one land cover type to another. Therefore, the classification has two main phases:

- an initial Dichotomous Phase, where eight major land cover types are distinguished, and

- a subsequent Modular-Hierarchical Phase, where the set of classifiers and their hierarchical arrangement are tailored to the major land cover type.

This approach allows the use of the most appropriate classifiers and prevents the use of inaccurate classifier combinations. To facilitate the complex classification process and ensure standardization, associated software tools have been developed that assist in the application of the standard, These tools should reduce heterogeneity between interpreters and between interpretations over time. The software assists the user to select the appropriate class using a step-by-step process, i.e. classifier by classifier. The tools assist in the use of the standard but are not part of this international standard. The flexible manner in which the classification is set up using these software tools involves the creation of classes at different levels of the system and the optional use of modifiers, environmental attributes and specific technical attributes in combination, coupled with the tremendous number of classes possible. The software can be used as a stand-alone product or used in combination with a digital image interpretation software suite, which will allow interpretation of imagery followed by labelling of the mapping units with the land cover classes.

Further definition of the Land Cover Class can be achieved by adding attributes. Two types of attributes, which form separate levels in the classification, are distinguished:

- Environmental Attributes are attributes (e.g. climate, landform, altitude, soil,lithology and erosion) that influence land cover but are not inherent features of it, and which should not be mixed with "pure" land cover classifiers, and

- Specific Technical Attributes are associated with specific technical disciplines. Thus for (Semi)Natural Vegetation, the Floristic Aspect can be added; for Cultivated Areas, the Crop Type; and for Bare Soil, the Soil Type.

All Primarily Vegetated land cover classes are derived from a consistent physiognomic structural conceptual approach that combines the classifiers Life Form, Cover and Height (in (Semi-)Natural Vegetation) and Life Form (in Cultivated Areas) with Spatial Distribution. The Primarily Non-Vegetated classes have a similar approach, using classifiers that deal with surface aspects, distribution or density, and height or depth.

The classification system generates mutually exclusive land cover classes, which comprise: (1) a unique Boolean formula (a coded string of classifiers used); (2) a standard name; and (3) a unique numerical code. Both the numerical code and standard name can be used to build an automatically generated Legend, with the classes that have been created being grouped according to the main land cover categories and their domains according to the level of detail. The nomenclature can be linked to a user-defined name in any language.

The advantages of the classifier, or parametric, approach are manifold. The system created is a highly flexible a priori land cover classification in which each land cover class is clearly and systematically defined, thus providing internal consistency. The system is truly hierarchical and applicable at a variety of scales. Re-arrangement of the classes based on regrouping of the classifiers used facilitates extensive use of the outputs by a wide variety of end-users. Accuracy assessment of the end product can be generated by class or by the individual classifiers forming the class. All land covers can be accommodated in this highly flexible system; the classification could therefore serve as a universally applicable reference base for land cover, thus contributing towards data harmonization and standardization.

Version 2 of the LCCS is an upgrade of the original version 1 (FAO, 2000) and has been developed on the experience gained from numerous FAO/UNEP and country mapping activities, including the Africover East Africa

Project as well as feedback from the end-user community. The new version of the LCCS comprises an upgrade to the software which is fully compatible with the previous version to ensure continuity of past and future LCCS mapping activities. Although this enhanced software is of interest to users of this standard, it is not directly part of this standard. The new version of the LCCS also includes some minor enhancements to the LCCS classification system. These include:

- Amelioration and modification of class names and class descriptions.

- Augmented types of classifiers and modifiers and environmental attributes to define an LCCS class.

- Increased number of possible combinations of classifiers/modifiers.

- Upgrade of the cartographic standards section. In addition to the original (cartographic) mixed-unit functions, another three types of mixed-unit function have been added.

5.3 Introduction

The main resource controlling primary productivity for terrestrial ecosystems can be defined in terms of land: the area of land available, land quality, moisture regime and edaphic character. Despite successful substitution of land-based resources with fossil fuels and mineral resources, land remains of prime importance (Darwin et al., 1996). Ref [11]. Land cover and land use represent the integrating elements of the resource base. Changes in land cover and land use affect global systems (e.g. atmosphere, climate and sea level) or occur in a localized fashion in enough places to have a significant effect (Meyer and Turner, 1992). Ref [33]. Land cover is the expression of human activities and, as such, changes with alterations in these. Hence, land cover is a geographical feature that can form a reference base for applications ranging from forest and rangeland monitoring, through production of statistics, planning, investment, biodiversity, climate change, to desertification control.

Humans have continually reshaped the Earth, but the present magnitude and rate are unprecedented. Nowadays, it is realized that it is very important to know how land cover has changed over time, in order to make assessments of the changes one could expect in the (near) future and the impact these changes will have on peoples' lives. As people are the main users of the land, it is important for any system to be oriented towards them.

Due to the lack of appropriate land cover data, many assessments have used models to delimit potential land cover (e.g. Alexandratos, 1995). Ref [1]. Although the use of potential land cover is important in modelling simulated future scenarios, there are major limitations. Information describing current land cover is an important input for planning and modelling, but the quality of such data defines the reliability of the simulation outputs (Townshend, 1992; Belward, 1996). Ref [41]

In addition to a high demand for improved land cover data sets because of an increasing need to be able to precisely describe and classify land cover in order to develop sustainable land use systems, there is also a growing need for standardization and compatibility between data sets and for the possibility to map, evaluate and monitor wide areas in a consistent manner (Di Gregorio, 1991; Ref [14]; Reichert and Di Gregorio, 1995; Ref [36], Thompson, 1996 Ref [40]; FAO, 1995, 1997, Ref [24], [25]). Technical advances, such as the vast amount of remote sensing data that has become available from earth observation satellites, makes this increasingly possible (Di Gregorio, 1995, Ref [15]).

In 1993, UNEP and FAO organized a meeting to catalyse coordinated action towards harmonization of data collection and management and to take a first step towards an internationally agreed reference base for land cover and land use (UNEP/FAO, 1994, Ref [43]). This was required by the Africover Programme of the Environment and Natural Resources Service (SDRN), with its objective to map land cover for the whole of Africa, and needed a land cover reference system for operational use.

The objectives of the Africover Programme are to:

- respond to the need of a variety of end-users for land cover data;

- apply the methodology in mapping exercises, independent of the means used, which may range from high resolution satellite imagery to aerial photography;

- link with existing classifications and legends, allowing comparison and correlation; and

- support, to the extent possible, international ongoing initiatives in classification and definition of land cover.

The main objective of the initiative is the definition of a reference classification to respond to the need for standardization or harmonized collection of data, as mentioned in the United Nations Conference on Environment and Development's (UNCED) Agenda 21 Chapter 10, for which FAO is Task Manager within the United Nations system and to develop a common integrated approach to all aspects of land cover. This implies a methodology that is applicable at any scale, and which is comprehensive in the sense that any land cover identified anywhere in the world can be readily accommodated.

When developing LCCS, existing published classifications and legends, as well as nomenclatures, were analysed (Danserau, 1961, Ref [10]; Fosberg, 1961, Ref [29]; Eiten, 1968, Ref [21]; UNESCO, 1973, Ref [45]; Mueller-Dombois and Ellenberg, 1974, Ref [34]; Anderson et al., 1976, Ref [2]; Kuechler and Zonneveld, 1988, Ref [32]; CEC, 1993, Ref [7]; UNEP/FAO, 1994, Ref [43]; Duhamel, 1995, Ref [19]; Beek, De Bie and Driessen, 1997, Ref [5]), together with relevant FAO documents (Nègre, 1995, Ref [35]; Barisano, 1996, Ref [4]; Wyatt et al., unpubl. Ref [48]).

The initial concepts of the classification were discussed by the international Africover Working Group on Classification and Legend (Senegal, July 1996; Di Gregorio and Jansen, 1996c, Ref [19]; FAO, 1997, Ref [25]). The system was developed in collaboration with other international ongoing activities on classification of land cover, such as the U.S.Federal Geographic Data Committee (FGDC) – Vegetation Subcommittee and Earth Cover Working Group (ECWG); the South African National Land Cover Database Project (Thompson, 1996, Ref [40]); and the International Geosphere-Biosphere Programme (IGBP) – Data and Information System (DIS) Land Cover Working Group and Land Use and Land Cover Change (LUCC) Core Project. The first full operational version of the classification and software program was developed by the Africover – East Africa project (GCP/RAF/287/ITA) in cooperation with the Soil Resources, Management and Conservation Service (AGLS) of FAO.

The approach developed serves as the basis for a reference classification system with links to specific expertise, because it describes and allows correlation of land cover through a set of independent diagnostic criteria, classifiers, rather than being nomenclature based. Also, existing classifications and legends can be "translated" into the reference system, thus facilitating the use of existing historical materials. Re-arrangement of the classes, based on re-grouping of the classifiers used, facilitates the extensive use of the outputs by a wide variety of end-users.

6 Conceptual basis

6.1 Purpose

Many classification systems exist that have been developed for specific purposes or scales and are not suitable for other initiatives. Examples are: (Danserau, 196, Ref [10]; Fosberg, 1961, Ref [29]; Eiten, 1968, Ref [21]; UNESCO, 1973, Ref [45]; Mueller-Dombois and Ellenberg, 1974, Ref [34]; Kuechler and Zonneveld, 1988, Ref [32]; most of the current classification systems are built in a topic specific manner.

A proportion of the existing classifications are either vegetation classifications (e.g. Danserau, 196, Ref [10]; Fosberg, 1961, Ref [29]; Eiten, 1968, Ref [21]; UNESCO, 1973, Ref [45]; Mueller-Dombois and Ellenberg, 1974, Ref [34]; Anderson et al., 1976, Ref [2]; Kuechler and Zonneveld, 1988, Ref [32]), broad land cover classifications, or systems related to the description of a specific feature (e.g. agricultural areas). Thus, they are limited in their capacity to define the whole range of possible land cover classes. An illustration is the UNESCO Vegetation Classification (designed to serve primarily for vegetation maps at a scale of 1:1 000 000), which considers only natural vegetation, while all other vegetated areas, such as cultivated areas and urban vegetated areas, are ignored. Other vegetation classifications, even if they consider agricultural areas, do not describe these classes with the same level of detail as that used for the natural vegetation areas. In contrast, systems used to describe agricultural areas give very few details in their description of natural vegetation.

Many systems have been developed for a certain purpose, at a certain scale, and using a certain data type, such as the IGBP-DISCover global 1 km data set based on the National Oceanic and Atmospheric Administration – Advanced Very High Resolution Radiometer (NOAA-AVHRR). Hence the derived classes are strictly dependent on the means used (e.g. in the last-named example, the classes will be only those that can be detected using NOAA-AVHRR).

Many current classification systems are not suitable for mapping and subsequent monitoring purposes. The use of the type of diagnostic criteria and their hierarchical arrangement to form a class is very often in conflict with the ability to define a clear boundary between two classes. For monitoring, land cover changes take two forms: conversion from one category to another (e.g. from forest to grassland), and modification of conditions within one category (e.g. from cultivated area to intensively cultivated area). The broader and fewer the categories used to describe land cover, the fewer the instances of conversion from one to another. If land cover classes are as broad as “forest and woodland”, “arable land” and “permanent meadows and pastures” (from the FAO Production Yearbook) then forest fragmentation, shifts from rainfed to irrigated cultivated areas and less dense grass cover due to overgrazing will be registered as neither conversion nor modification. A multi-user-oriented classification system should capture both.

These classification systems serve their purpose within their topic areas, but are not general classification systems. The capabilities of these classification systems within their domains of applicability establish the requirtements for a more general classification system. These requirements are addressed in the following sub-clauses.

6.2 Consistency

In most current classifications, the criteria used to derive classes are not systematically applied. Often, the use of different ranges of values depends on the importance given by the user to a particular feature (e.g. in many systems the cover ranges to distinguish treedominated areas are many, whereas only one single cover range is used to define shrub- or grass- dominated areas).

In some classifications the class definition is imprecise, ambiguous or absent. This means that these systems fail to provide internal consistency. An example is the frequency with which classes in the CORINE (Coordination of Information on the Environment) Land Cover system overlap with other classes elsewhere in the same classification (CEC, 1993), Ref [7].

In most systems, the full combination of diagnostic elements describing a class is not considered, e.g. a system that describes vegetation with the diagnostic criteria of three ranges of cover matched with three ranges of height must consistently apply these ranges for all life forms considered. The reason why most systems fail in application of this basic classification rule is that the entire set of permutations of the possible classifiers would lead to a vast number of classes that cannot be handled with the current methods of class description. Thus, in the example above, if there were 10 classes of each, the result would be 100 combinations. Therefore, the current systems often leave gaps in the systematic application of the diagnostic criteria used.

Very often the systems contain a number of classes, which, due to their interrelation and hierarchical structure, appear to be a proportion of a broader set of classes. Thus, these types of systems are mere legends. The characteristic of legends is that only a proportion or sub-set of the entire range of possible classes is described. Such legends have the disadvantage that the user cannot refer back to a classification system, which precludes comparisons with other systems.

Threshold values are very often derived from knowledge of a specific geographic area, so that elsewhere the class boundary definition between two classes may become unclear, due to overlaps or gaps. In these cases, any comparisons will be impossible or inaccurate.

6.3 Underlying common principle

An underlying common principle has not often been defined in land cover classification. A mixture of different features is used to define a class, especially features such as climate, geology, soil type and landform (thus, in “tropical rain forest” the term “tropical”, which is usually climate related, is used to describe a certain floristic composition). Features such as climate, geology and landform influence land cover but are not inherent features of it. This type of combination is frequently found and is often applied in an irregular way, with no hierarchy. This may lead to ambiguity in the definition of the class.

Classification of vegetation using the diagnostic criteria of “height” and “cover” will lead to a different perspective of the same feature in comparison with the use of “leaf phenology” and “leaf type” (Figure 1). It is therefore important to come to a basic understanding of the criteria to be used as underlying principles for land cover description.

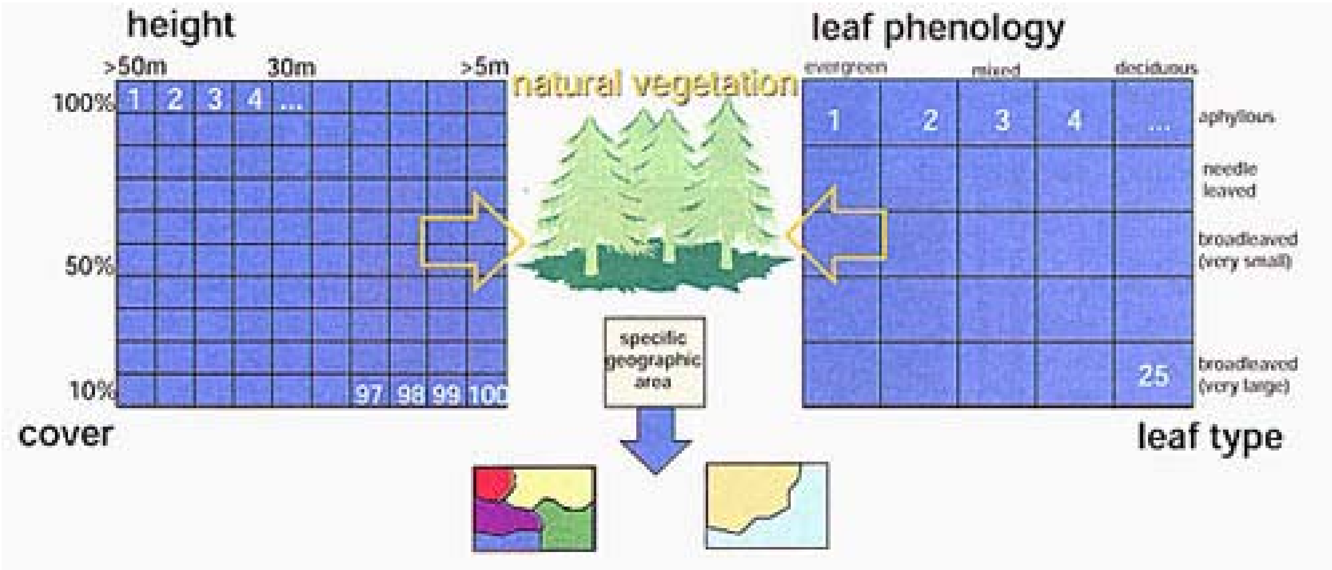

Figure 1 - An example of description of a land cover using a different underlying principle

6.4 *A priori* classification systems

In an *a priori* classification system classes are pre-arranged. The use of such a classification assumes that all possible classes can be derived, independent of scale and tools used, from the system. Having all classes pre-defined in the system is the intrinsic rigidity of an *a priori* classification system. The advantage of such a system is mainly that it is the most effective way to produce standardization of classification results among user communities. The disadvantage is that to be able to describe consistently any land cover occurring anywhere in the world, one needs an enormous number of pre-defined classes. Such a system should be flexible in the sense that any occurring land cover can be accommodated. How can one introduce this type of flexibility while using the “classical” approach of class names and descriptions?

This can be achieved by increasing the number of classes in an a priori system, but the problem then arises of how the users will find their way through a “jungle” of class names (Figure 2). Furthermore, this situation makes standardization more difficult to attain, as every user may have a slightly different opinion on how to interpret some classes because the class boundary definitions between classes will be based on very slight, subjective differences.

The wrong, or different, designation of the same land cover feature among various classes will undermine the standardization process that is one of the primary objectives of the classification system. Ultimately, the attempt to harmonize will fail. The *a priori* classification approach appears to be a vicious circle: the attempt to create this type of classification as a tool for standardization obliges one to accommodate the enormous variety of occurring land cover in a limited number of more generic classes, while the endeavour to create more classes increases the danger of lack of standardization, thus sabotaging the basic principle forming the starting premise.

The above illustrates that there is not as much compatibility between classification systems, or between classification and legend, as may be desired. There are numerous inconsistencies in definition of classes, class boundaries, in the use of threshold values, etc. However useful the current classifications may be, these factors limit the possibility of using these methods on a broad range of applications.

In the context of developing a new system, it is fundamental to identify the criteria to which any reference classification, to the extent possible, should adhere (Table 1).

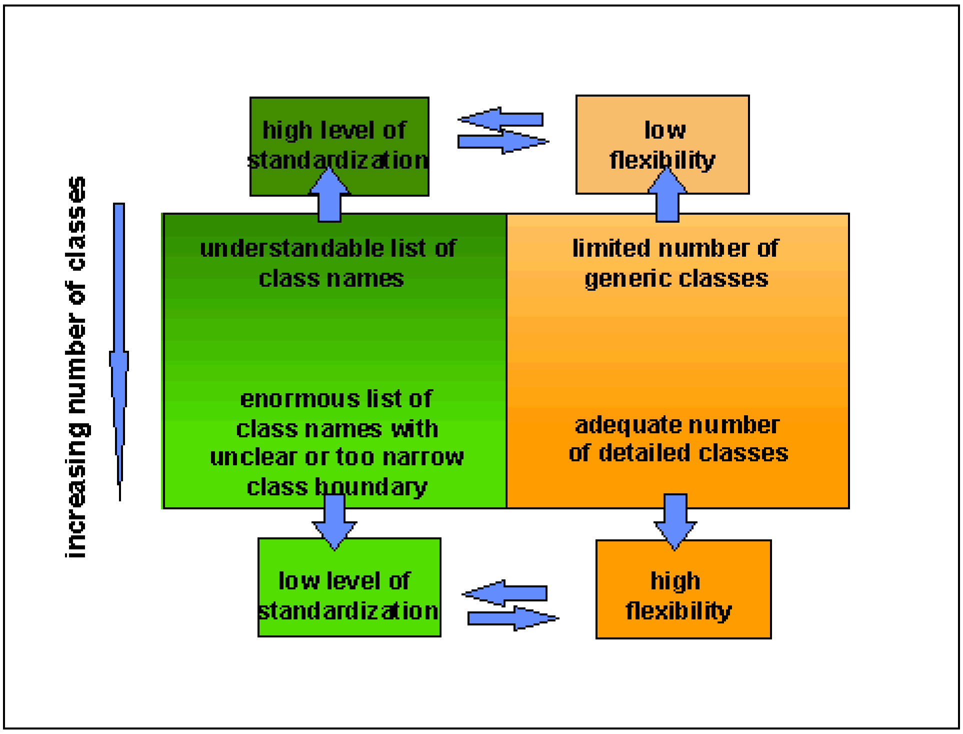

Figure 2 - Problem of the current a priori classifications in relation to their flexibility

Table 1 - GENERAL CRITERIA FOR A REFERENCE CLASSIFICATION
- comprehensive, scientifically sound and practically oriented;
- capable of meeting the needs of a variety of users (neither single-project oriented nor taking a sectoral approach); users can use just sub-sets of the classification and develop them to their own specific needs;
- potentially applicable as a common reference system and facilitating comparisons between classes derived from different classifications;
- a flexible system that can be used at different scales and at different levels of detail, allowing cross-reference of local and regional maps with continental and global maps without loss of information;
- able to describe the complete range of land cover features (e.g. forest and cultivated areas as well as ice and bare land, etc.), with clear class boundary definitions that are unambiguous and unique;
- adapted to fully describe the whole variety of land cover types with the minimum set of classifiers necessary (the fewer the classifiers used in the definitions, the less the error expected and the less time and resources necessary for field validation); and
- based on a clear and systematic description of the class, where the diagnostic criteria used to define a class must be clearly defined, with pure land cover criteria distinct from environmental

criteria (e.g. climate, floristic and altitude), as the latter influence land cover but are not inherent features of it.

6.5 *The basis for a new approach*

6.5.1 Definition adopted for land cover

lThe common integrated approach adopted here defines land cover *as the observed (bio)physical cover on the earth's surface*, but, in addition, it is emphasized that land cover must be considered a geographically explicit feature that other disciplines may use as a geographical reference (e.g. for land use, climatic or ecological studies).

Land is a basic source of mass and energy throughput in all terrestrial ecosystems, and land cover and land use represent the integrating elements of the resource base. Land cover, being the expression of human activities, changes with modifications in these activities. Therefore, land cover as a geographically explicit feature can form a reference basis for other disciplines.

6.5.2 LCCS approach to classification

6.5.2.1 Increasing flexibility while maintaining mappability

To create a standardized, hierarchical, consistent, *a priori* classification system containing systematic and strict class boundary definitions implies the basic requirement of having to build flexibility into the classification system. In this context, "flexibility" can have various meanings. First of all, flexibility should address the potential for the classification system to describe enough classes to cope with the real world. At the same time, however, flexibility should adhere to strict class boundary definitions that should be unambiguous and clear. In addition, the classes in such a system should be as neutral as possible in the description of a land cover feature in order to answer to the needs of a wide variety of endusers and disciplines.

Many current classification systems are not generally suitable for mapping, and subsequent monitoring, purposes. The integrated approach requires clear distinction of class boundaries. Furthermore, the use of diagnostic criteria and their hierarchical arrangement to form a class should be a function of the mappability, i.e. the ability to define a clear boundary between two classes. Hence, diagnostic criteria should be hierarchically arranged in order to assure at the highest levels of the classification a high degree of geographical accuracy.

How does one increase the classification system's flexibility while maintaining the principle of mappability and aiming at standardization? These prerequisites can only be accomplished if the classification has the possibility of generating a high number of classes with clear boundary definitions. In other words, it should be possible to delineate a large number of classes in order to match the enormous variation of land cover features, while maintaining the clear distinction of class boundaries. In current classification systems this possibility is hampered by the manner in which these classifications are set up. Differences between classes can only be derived from class descriptions. Therefore, it would be very difficult for the user to distinguish between such classes just based upon class names or unsystematic descriptions, as is the case with most of the current classification systems.

6.5.2.2 Basic principle

One of the basic principles adopted in the LCCS approach is that a given land cover class is defined by the combination of a set of independent diagnostic attributes, the so-called classifiers. The increase of detail in the description of a land cover feature is linked to the increase in the number of classifiers used. In other words, the more classifiers added, the more detailed the class. The class boundary is then defined either by the different amount of classifiers or by the presence of one or more different types of classifiers. Thus, emphasis is no longer on the class name, but on the set of classifiers used to define this class.

6.5.2.3 Issues impeding application of the new approach

The straightforward application of this approach is hampered by two main factors. First, land cover should describe the whole observable (bio)physical environment and therefore deals with a heterogeneous set of classes. Obviously, a forest is best defined using a set of classifiers that differ from those used to describe snow-covered areas. Instead of using the same set of classifiers to describe such heterogeneous features, in this approach the classifiers are tailored to each land cover feature. According to the general concept of an *a priori* classification, it is fundamental to the system that all the combinations of the classifiers must be created in the system. By tailoring the set of classifiers to the land cover feature, all combinations can be made without having a tremendous number of theoretical but redundant combinations of classifiers. Secondly, two distinct land cover features, having the same set of classifiers to describe them, may differ in the hierarchical arrangement of these classifiers in order to ensure high mappability.

6.5.3 Land Cover Classification System design criteria

Land cover classes are defined by a string of classifiers, but due to the heterogeneity of land cover, and with the aim of achieving a logical and functional hierarchical arrangement of the classifiers, certain design criteria have been applied.

The Land Cover Classification System (LCCS) has two main phases (Figure 3).

The initial Dichotomous Phase, has eight major land cover types:

- Cultivated and Managed Terrestrial Areas
- Natural and Semi-Natural Terrestrial Vegetation
- Cultivated Aquatic or Regularly Flooded Areas
- Natural and Semi-Natural Aquatic or Regularly Flooded Vegetation
- Artificial Surfaces and Associated Areas
- Bare Areas
- Artificial Waterbodies, Snow and Ice, and
- Natural Waterbodies, Snow and Ice.

This is followed by a subsequent Modular-Hierarchical Phase, in which land cover classes are created by the combination of sets of pre-defined classifiers. These classifiers are tailored to each of the eight major land cover types. The tailoring of classifiers in the second Phase allows the use of most appropriate classifiers to define land cover classes derived from the major land cover types and at the same time reduces the likelihood of impractical combinations of classifiers. This results in a land cover class defined by:

- a Boolean formula showing each classifier used (all classifiers are coded);
- a unique number for use in Geographical Information Systems (GIS), and
- a name, which can be the standard name as supplied or a user-defined name.

6.5.4 Dichotomous Phase

As stated above, a dichotomous key is used at the main level of classification to define the major land cover classes (Figure 3). Each major land cover type is defined as shown in Table 2 to Table 4.

Three classifiers are used in the Dichotomous Phase, namely Presence of Vegetation, Edaphic Condition and Artificiality of Cover. These three classifiers have been hierarchically arranged, although independent of this arrangement the same eight major land cover types would be keyed out. The hierarchical arrangement is thus not important in this Phase, but is a guiding principle in the subsequent Modular-Hierarchical Phase.

6.5.5 Modular-Hierarchical Phase

In this phase the creation of the land cover class is given by the combination of a set of predefined pure land cover classifiers. This set of classifiers is different for each of the eight main land cover types. This difference is due to the tailoring of the classifiers to their respective type (Figure 4).

These pure land cover classifiers can be combined with so-called *attributes* for further definition. Two types of attributes, which form separate levels in the classification, are distinguished (see Figure 4 for two examples):

- *Environmental Attributes*. These attributes (e.g. climate, landform, altitude, soils, lithology, erosion) influence land cover but are not inherent features of it and should not be confused with “pure” land cover classifiers. These attributes can be combined in any user-defined order.

- *Specific Technical Attributes.* These attributes refer to the technical discipline. Thus, for (Semi-) Natural Vegetation, the *Floristic Aspect* can be added (e.g. the methodology of how this information was collected, as well as a list of species); for Cultivated Areas, the *Crop Type* can be added, either according to broad categories commonly used in statistics or by crop species; and for Bare Soil, the *Soil Type* according to the FAO/UNESCO Revised Soil Legend can be added. These attributes can be added freely to the pure land cover class without any conditions.

The user is obliged to start with the pure land cover classifiers. However, at any time the user can stop – dependent upon the level of detail required – and derive a land cover class (Table 5). Further definition of this class can be achieved by adding a single or a combination of any of the other types of attributes. These attributes are not hierarchically ordered and selection of them will generate a separate coded string.

Table 2

Distinctions at main dichotomous phase	
Classifiers used	**Land Cover Class Name and Description**
DICHOTOMOUS PHASE: INITIAL-LEVELDISTINCTION	
Primarily vegetated *Primarily vegetated*	**A. Primarily Vegetated Areas** This class applies to areas that have a vegetative cover of at least 4% for at least two months of the year. This cover may consist of *Woody* life forms (Trees, Shrubs), *Herbaceous* life forms (e.g. Forbs, and Graminoids) or a combination of them, or consist of life forms of *Lichens/Mosses* (only when other life forms are absent). A separate cover condition exists for Lichens/Mosses that can be only applied if this life form contributes at least 25% to the total vegetative cover
Primarily non-vegetated *Primarily non- vegetated*	**B. Primarily Non-Vegetated Areas** This class includes areas that have a total vegetative cover of less than 4% for at least 10 months of the year, or an absence of Woody or Herbaceous life forms and with less than 25% cover of Lichens/Mosses

Table 3

Distinctions at second level	
Classifiers used	**Land Cover Class Name and Description**
DICHOTOMOUS PHASE: SECOND-LEVELDISTINCTION	
Primarily vegetated *Edaphic Condition:* *Terrestrial*	**A1. Terrestrial Primarily Vegetated Areas** The vegetation is influenced by the edaphic substratum.
Primarily non-vegetated *Edaphic Condition:* *Terrestrial*	**B1. Terrestrial Primarily Non-Vegetated Areas** The cover is influenced by the edaphic substratum.
Primarily vegetated *Edaphic Condition:* *Aquatic or regularly flooded*	**A2. Aquatic or Regularly Flooded Primarily Vegetated Areas** The environment is significantly influenced by the presence of water over extensive periods of time. The water is the dominant factor determining natural soil development and the type of plant communities living on its surface. Includes marshes, swamps, bogs and all areas where water is present for a substantial period regularly every year. This class includes floating vegetation.

Primarily non-vegetated *Edaphic Condition:* *Aquatic or regularly flooded*	**B2. Aquatic or Regularly Flooded Primarily Non-Vegetated Areas** The environment is significantly influenced by the presence of water over an extensive period of time each year.

Table 4

Distinctions at third level of the dichotomous phase into eight major land cover types	
Classifiers used	**Land Cover Class Name and Description**
DICHOTOMOUS PHASE: TERTIARY-LEVELDISTINCTION	
Primarily vegetated Terrestrial *Artificiality of Cover:* *Artificial/managed*	**A11. Cultivated and Managed Terrestrial Areas** This class refers to areas where the natural vegetation has been removed or modified and replaced by other types of vegetative cover of anthropogenic origin. This vegetation is artificial and requires human activities to maintain it in the long term. In between the human activities, or before starting crop cultivation, the surface can be temporarily without vegetative cover. Its seasonal phenological appearance can be regularly modified by humans (e.g. tillage, harvest, and irrigation). All vegetation that is planted or cultivated with an intent to harvest is included in this class (e.g. wheat fields, orchards, rubber and teak plantations).
Primarily vegetated Terrestrial *Artificiality of Cover:* *(Semi-)natural*	**A12. Natural and Semi-Natural Vegetation** Natural vegetated areas are defined as areas where the vegetative cover is in balance with the abiotic and biotic forces of its biotope. Semi-natural vegetation is defined as vegetation not planted by humans but influenced by human actions. These may result from grazing, possibly overgrazing the natural phytocenoses, or else from practices such as selective logging in a natural forest whereby the floristic composition has been changed. Previously-cultivated areas that have been abandoned and where vegetation is regenerating are also included. The secondary vegetation developing during the fallow period of shifting cultivation is a further example. The human disturbance may be deliberate or inadvertent. Hence semi-natural vegetation includes vegetation due to human influences but which has recovered to such an extent that species composition and environmental and ecological processes are indistinguishable from, or in a process of achieving, its undisturbed state. The vegetative cover is not artificial, in contrast to classes A11 and A24, and it does not need human action to be maintained in the long term..
Aquatic or Regularly Flooded *Artificiality of Cover:* *Artificial/managed*	**A23. Cultivated Aquatic or Regularly Flooded Areas** This class includes areas where an aquatic crop is purposely planted, cultivated and harvested and which is standing in water over extensive periods during its cultivation period (e.g. paddy rice, tidal rice and deepwater rice). In general, it is the emerging part of the plant that is fully or partly harvested. Other plants (e.g. for purification of water) are free-floating. They are not harvested but they are maintained. This class excludes irrigated cultivated areas.
Primarily vegetated Aquatic or Regularly Flooded *Artificiality of Cover:* *(Semi-)natural*	**A24. Natural and Semi-Natural Aquatic or Regularly Flooded Vegetation** This class describes areas that are transitional between pure terrestrial and aquatic systems and where the water table is usually at or near the surface or the land is covered by shallow water. The predominant vegetation, at least periodically, comprises hydrophytes. Marshes, swamps, bogs or flats where drastic fluctuations in water level or high concentration of salts may prevent the growth of hydrophytes are all part of this class. The vegetative cover is significantly influenced by water and dependent on flooding (e.g. mangroves, marshes, swamps and aquatic beds). Occasionally-flooded vegetation within a terrestrial

	environment is not included in this class. Natural Vegetated Aquatic habitats are defined as biotopes where the vegetative cover is in balance with the influence of biotic and abiotic forces. Semi-Natural Aquatic vegetation is defined as vegetation that is not planted by humans but which is influenced directly by human activities that are undertaken for other, unrelated purposes. Human activities (e.g. urbanization, mining and agriculture) may influence abiotic factors (e.g. water quality), affecting species composition. Furthermore, this class includes vegetation that developed due to human activities but which has recovered to such an extent that it is indistinguishable from its former state or which has built up a new biotope which is in balance with the present environmental conditions. A distinction between Natural and Semi-Natural Aquatic Vegetation is not always possible because human activities distant to the habitat may create chain reactions that ultimately disturb the aquatic vegetative cover. Human activities may also take place deliberately to compensate for disruptive effects with the aim of keeping a “natural” state.
Primarily non-vegetated Terrestrial *Artificiality of Cover:* *Artificial/managed*	**B15. Artificial Surfaces and Associated Areas** This class describes areas that have an artificial cover as a result of human activities such as construction (cities, towns, transportation), extraction (open mines and quarries) or waste disposal.
Primarily non-vegetated Terrestrial *Artificiality of Cover:* *(Semi-)natural*	**B16. Bare Areas** This class describes areas that do not have an artificial cover as a result of human activities. These areas include areas with less than 4% vegetative cover. Included are bare rock areas, sands and deserts.
Primarily non-vegetated Aquatic or Regularly Flooded *Artificiality of Cover:* *Artificial/managed*	**B27. Artificial Waterbodies, Snow and Ice** This class applies to areas that are covered by water due to the construction of artefacts such as reservoirs, canals, artificial lakes, etc. Without these, the area would not be covered by water, snow or ice.
Primarily non-vegetated Aquatic or Regularly Flooded *Artificiality of Cover:* *(Semi-)natural*	**B28. Natural Waterbodies, Snow and Ice** This class refers to areas that are naturally covered by water, such as lakes, rivers, snow or ice. In the case of rivers, the lack of vegetation cover is often due to high flow rates and/or steep banks. In the case of lakes, their geological origin affects the life conditions for aquatic vegetation. The following circumstances might cause water surfaces to be without vegetation cover: depth, rocky basins, rocky and/or steep shorelines, infertile washed-in material, hard and coarse substrates

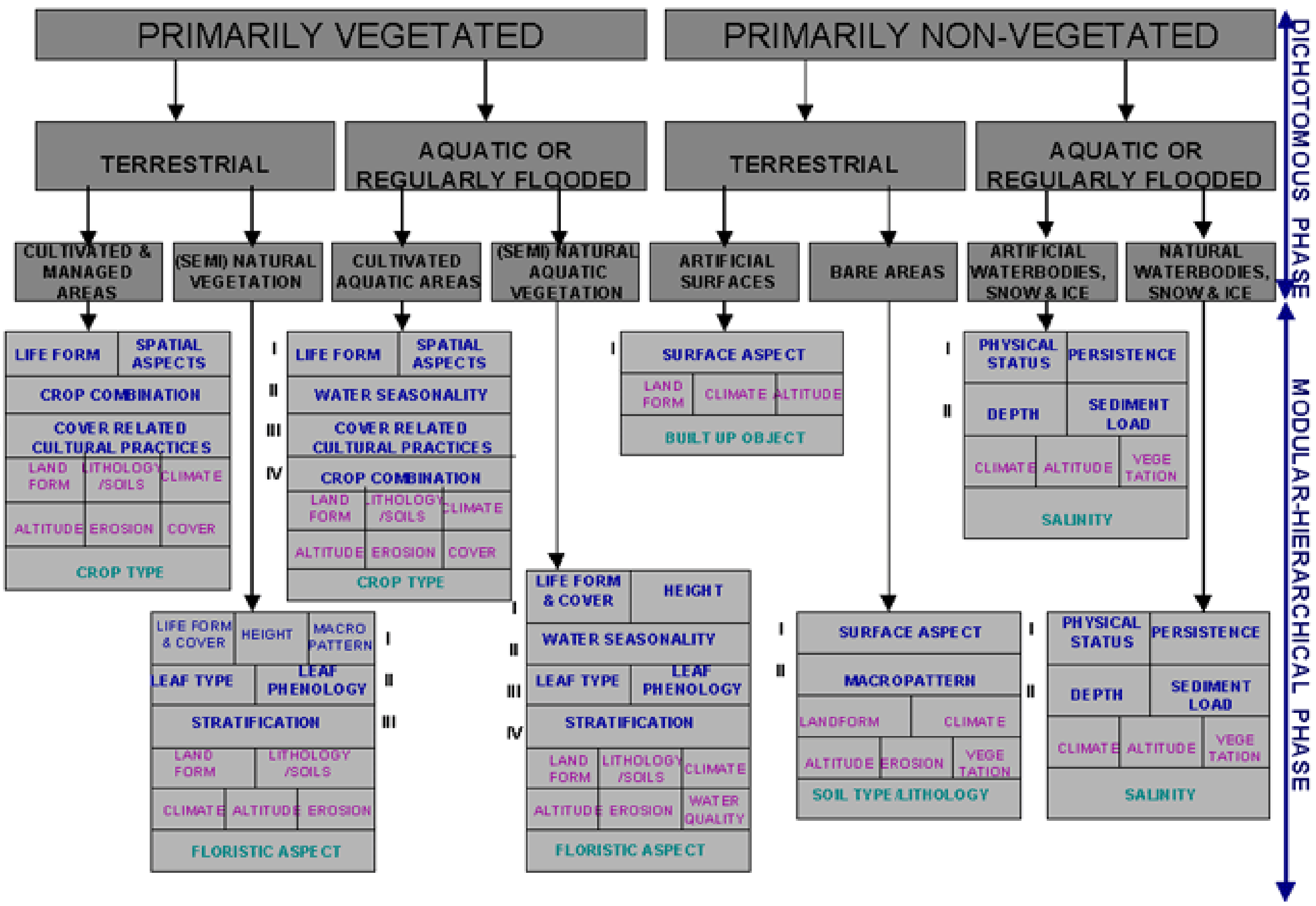

Figure 3 - Overview of the Land Cover Classification System, its two phases and the class

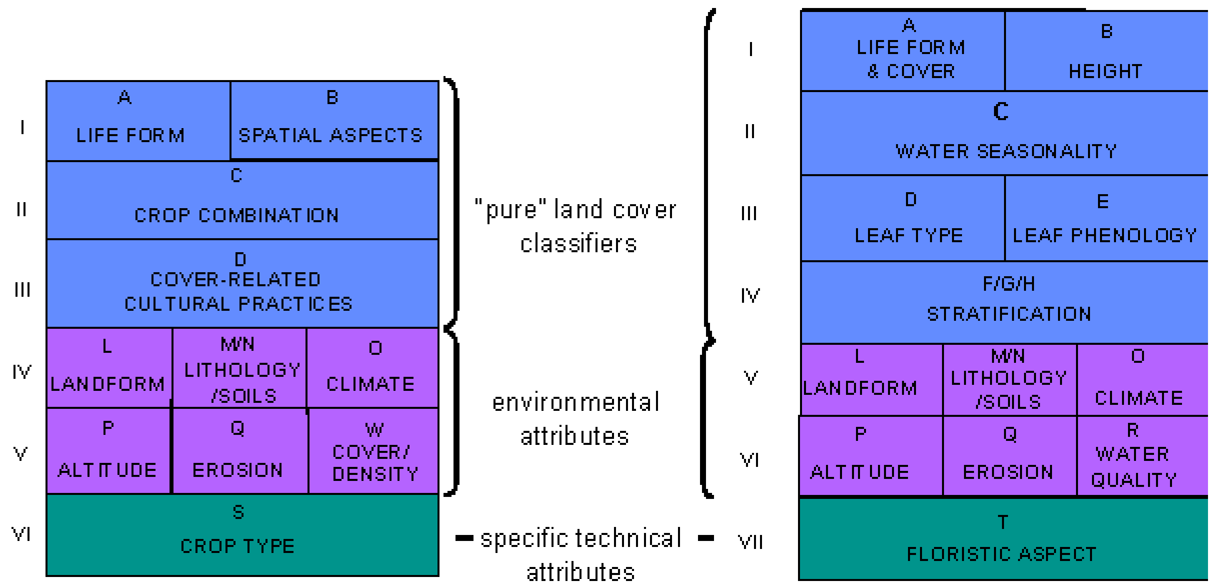

Figure 4 - The Modular-Hierarchical Phase

Example of tailoring of the classifiers and attributes for ”Cultivated and Managed Terrestrial Lands” (left) and “Natural and Semi-Natural Aquatic or Regularly Flooded Vegetation” (on the right).

Since the classification is suitable for mapping purposes, the system gives high priority to “mappability” and the user needs to follow specific rules:

- A higher level of land cover classifier must be used before going to a lower level (because mappability is high at higher levels and decreases with lower levels).
- The *modifiers*, which refine the classifier further, are optional and do not necessarily need to be determined.
- All land cover classifiers at one level of the classification have to be determined before the system allows one to go to the next level.
- At any time inside a land cover classifier level the user can stop, and a mutually exclusive class is defined.
- All land cover classes defined in such a way are hierarchically arranged in the Legend (see Legend Module).
- At any time the user can further define the land cover class using environmental or specific technical attributes, alone or in combination. These attributes will add a second, separate code to the land cover class because they are not inherent features of land cover.
- Each land cover class is defined by a Boolean formula (i.e. a combination of the classifiers used), a unique code (numerical) and a name (nomenclature).

Table 5

Example of the formation of land cover classes			
EXAMPLE: “NATURAL AND SEMI-NATURAL TERRESTRIAL VEGETATION” (A12)			
Classifiers used	**Boolean formula**	**Standard class name**	**Code**
Life form and cover	A3A10	Closed forest	20005
Height	A3A10B2	High closed forest	20006
Spatial distribution	A3A10B2C1	Continuous closed forest	20007
Leaf type	A3A10B2C1D1	Broad-leaved closed forest	20095
Leaf phenology	A3A10B2C1D1E2	Broad-leaved deciduous forest	20097
2nd layer: LF, C, H	A3A10B2C1D1E2F2F5F7G2	Multi-layered broad-leaved deciduous forest	20628
3rd layer: LF, C, H	A3A10B2C1D1E2F2F5F7G2	Multi-layer broad-leaved deciduous forest with emergents	20630

6.6 *Skipping the dichotomous phase*

For some specific mapping applications, classes belonging to primarily vegetated areas, it is not feasible to separate Terrestrial from Aquatic and/or Artificial from Natural/Semi-Natural Vegetation. In these situations it is possible to skip the dichotomous phase. Specific modes allow for predefined states replacing the need for the dichotomous phase. These modes are:

Mode 0 – This is the default mode where the user has previously gone through the dichotomous phase to build up the class using the classifier combination.

Mode 1 – Here the user skips the division between terrestrial and aquatic in the dichotomous phase. This mode accesses the modular hierarchical phase only for Terrestrial Cultivated and Managed Areas, and Semi-Natural Vegetation. All the classes of Cultivated and Managed Land and/or Semi-Natural/Natural Vegetation generated under this mode function will therefore have no differentiation between edaphic conditions (Terrestrial or Aquatic – Regularly Flooded)

Mode 2 – Here the user selects the “Primarily Vegetated” and “Terrestrial”. This mode omits the differentiation between ‘Cultivated and Managed Terrestrial Area(s)’ and ‘Natural and Semi-Natural Terrestrial Vegetation’. With Mode 2 setting there is only access to the modular hierarchical phase from ‘Terrestrial Natural/Semi-Natural

Vegetation' That means that all classes of 'Terrestrial Natural/Semi-Natural Vegetation' generated with this mode function will not be differentiated according to the "artificiality" of vegetation.

Mode 3 – This is similar to Mode 2, with the exception that in the upper part of the dichotomous phase the 'Aquatic or Regularly Flooded' alternative has been selected instead of the 'Terrestrial' option. This allows access to the modular hierarchical phase only from 'Aquatic/Regularly Flooded Natural/Semi-Natural

Mode 4 – Here the user skipps the division between 'Terrestrial – Aquatic or Regularly Flooded' and 'Cultivated and Managed Terrestrial Area(s) – Natural and Semi-Natural Terrestrial Vegetation'. This will allow access to the modular hierarchical phase only from 'Terrestrial Semi- Natural/Natural Vegetation'.

A legend can be set up combining classes built up in different mode functions. Mixed units can be established in any LCCS mode function. However, to form a mixed unit (example A/B), the user has to remain in the same mode function. In the software that supports the LCCS the tools are provided for managing modes assists in managing these modes. See [27] clause 3.3.

6.7 *Concepts for primarily vegetated areas*

There are different ways of making an orderly arrangement of the *Primarily Vegetated Areas*, with varying success according to region or purpose. Vegetation has a multitude of properties and features and a certain degree of abstraction is required when classifying. However, agreement could be reached on selection of a relatively small number of diagnostic criteria to identify plant communities.

Plant communities, or phytocenoses, are characterized by two important features:

- all plant communities consist of *growth forms*; and
- all plant communities consist of *plant species*.

This applies to all phytocenoses on earth (Kuechler and Zonneveld, 1988, Ref [32]). Growth forms (e.g. trees, shrubs, herbaceous, etc.) are so important that various vegetation scientists have used them as criteria for classification (Danserau, 1961, Ref: [10]; Mueller-Dombois and Ellenberg, 1974, Ref [34]). The growth forms are distributed within the plant community in layers or *strata*. This stratification is common and the distinction of the individual strata is of fundamental importance when analysing the plant community. Plant communities are not limited to vertical arrangement into layers: they are also arranged horizontally (i.e. the horizontal spatial distribution).

Thus, when observing plant communities and considering their growth forms, two factors are fundamental:

- *physiognomy*, the overall appearance of the vegetation; and
- vege*tation structure*, which is defined as "the spatial distribution pattern of growth forms in a plant community" (Kuechler and Zonneveld, 1988, Ref [32]. The structure, then, describes the individual strata, usually characterized by height and density or coverage of the respective growth forms.

At the same time, a plant community consists of *taxa* (botanical species) that are usually unevenly distributed insofar as some may be common, or dominant, while others are less conspicuous. The component taxa can be used to describe the plant community as well as the structure. A description using taxa is called *floristic composition* of the plant community. The floristic composition usually contains all species, though it is unusual to include the rare or incidental ones.

The various existing classification systems have emphasized one or other of the above (e.g. physiognomic-structural systems; floristic systems and physiognomic-floristic systems). There is no doubt that a full description of a plant community must consider both physiognomic-structural and floristic aspects. A phytocenose can have the same structural aspect but different floristic composition, as well as the same floristic composition but a different structural aspect. However, problems arise when attempting to incorporate both types of information in a single classification system.

In LCCS, *Natural and Semi-Natural Vegetation*, both in the *Terrestrial Areas* (A12) and *Aquatic or Regularly Flooded Areas* (A24), is classified using a pure physiognomicstructural method. The parameters considered are: (1) physiognomy; (2) vertical and horizontal arrangement; (3) leaf type; and (4) leaf phenology of plants. This concept has been adopted with the conviction that only a pure structural representation of vegetation is able to incorporate, without any confusion of terms, floristic aspects of vegetation as well as environmental attributes (e.g. landform, climate, altitude, etc.). The proposed classification allows the user to add freely these attributes at any level of the structural land cover class created.

Users not familiar with classical vegetation classification and mapping (Eiten, 1968, Ref [21]; UNESCO, 1973, Ref [45]; White, 1983, Ref [47]; Kuechler and Zonneveld, 1988, Ref [32]) or ecological studies should be able to build up a scientifically sound vegetation classification by following the Land Cover Classification System. This will avoid the separation between classical vegetation classification and land cover classification. A variety of users should be able to apply the results of the classification, even those who are not specialized in vegetation mapping.

The physiognomic-structural approach selected for classification of vegetated areas in a land cover classification system poses a challenge with regard to classification of vegetated areas other than (semi-)natural vegetated areas, namely cultivated and urban vegetated areas. These managed vegetated areas are also characterized by plant communities having growth forms and taxa, a structure and a floristic composition. Therefore, the physiognomic-structural approach adopted is equally applicable to such areas. Using the same approach to describe and classify this type of area at a certain level of detail has the advantage that all *Primarily Vegetated Areas* can be compared.

6.7.1 Natural and Semi-Natural Vegetation (A12 and A24)

6.7.1.1 General rules for classification

Before starting to use the classifiers, the user has to take into account some basic rules governing the concepts of classification of (Semi-)Natural Vegetation, namely:

- the definition of *Life Form*, and
- the definition of *dominance*.

These two main aspects are very important and must be carefully determined because the determination of main Life Form has consequences for the selections available at subsequent levels. Certain choices at a high level of the system may preclude choices at lower levels.

- *Life Form* of a plant is defined by its physiognomic aspect: *Woody Life Forms* are distinguished from *Herbaceous Life Forms* and from *Lichens/Mosses Life Forms*.

- The Woody Life Form is subdivided into Trees and Shrubs. A condition of *Height* is applied to separate *Trees* and *Shrubs*. Plants higher than 5 m are classified as *Trees*. In contrast, plants lower than 5 m are classified as *Shrubs*. These general rules are subjected to the following exception: a plant with a clear physiognomic aspect of trees can be classified as *Trees* even if the *Height* is lower than 5 m but more than 3 m. In this case, a sub-condition of physiognomic aspect is added to the *Height* condition.

- A special class, called *Woody*, had been created for plants included into the 2-7 m range, when no further definition into Tree or Shrubs is specified. The Woody class can be applied basically in two cases: the vegetation is an intricate mixture of both trees and shrubs which cannot be distinguished and with height included in the 2-7 m range; the user is not interested in further subdivision into trees or shrubs or has no information about it. If the user does not know if the vegetation is composed by Trees or Shrubs, the use of mixed units is recommended (A//B).

These are the limits recommended for *Life Form* distinction, but exceptions are allowed:

- Plants essentially herbaceous but with a woody appearance (e.g. bamboos and ferns) are classified as *Trees* if the height is more than 5 m, and as *Shrubs* if the height is less than 5 m.

Concerning the concept of dominance, two criteria need to be considered:

-. The main criterion is the **uppermost canopy layer**. This means that the dominant layer goes from *Woody Life Forms* (Tree/Shrub or Woody canopy) to *Herbaceous Life Form* (Forbs or Graminoids).

-. This general rule is subject to a **sub-condition of Cover**: It is only valid if the dominant Life Form has a Cover either *Closed* or *Open*. If the Life Form is *Sparse*, the dominance goes to another Life Form that has a Closed or Open cover (Figure 1).

When the user has decided these two main aspects, the building of classes can start. The rules explained above show that in order to determine a (Semi-)Natural Vegetation class, a minimum of three classifiers need to be selected:

- Life Form
- Cover
- Height

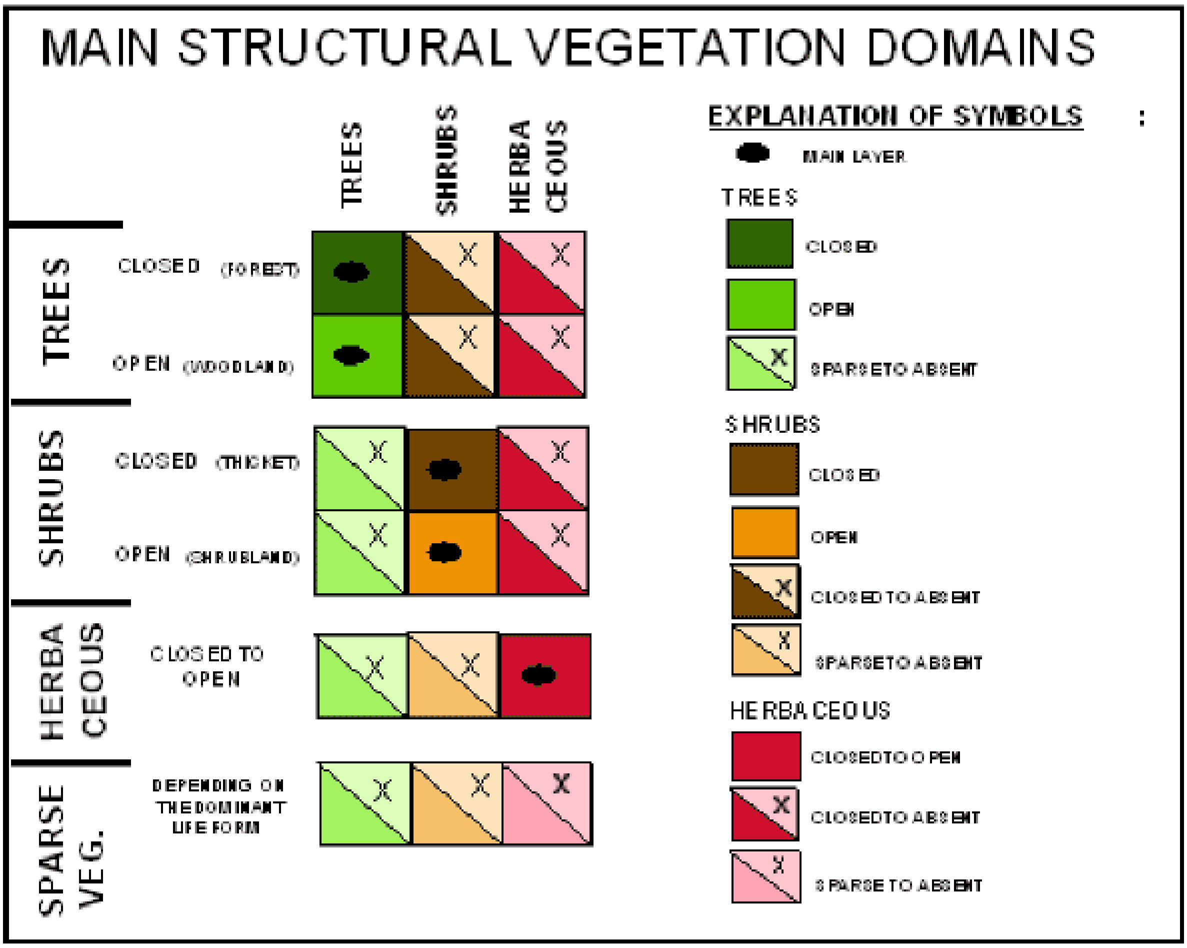

Figure 5 - Main structural vegetation domains

These are the minimum elements required to form a Natural or Semi-Natural Vegetated land cover class, for both Terrestrial and Aquatic or Regularly Flooded Areas. Because Height (in its standard denotation) is automatically linked to the Life Form chosen, the classifiers needed to be determined are actually two: Life Form and Cover.

6.7.1.2 Main structural vegetation domains

These are the minimum elements required to form a *Natural* or *Semi-Natural* Vegetated land cover class, for both *Terrestrial* and *Aquatic or Regularly Flooded Areas*. Because *Height* (in its standard denotation) is automatically linked to the Life Form chosen, the classifiers needed to be determined are actually two: *Life Form* and *Cover*.

6.7.1.2.1 Life Form and Cover

A Life Form is a group of plants having certain morphological features in common (Kuechler and Zonneveld, 1988, Ref [32]). According to the quality of the main axis or shoots, a further distinction is made into Woody Life Forms or Herbaceous Life Forms. For further subdivision, the following growth form criteria can be applied:

- *Branching symmetry*, subdividing Trees and Shrubs; and
- *Herbaceous plant physiognomy*, subdividing *Forbs* from *Graminoids* (Strasburger et al., 1983; Kuechler and Zonneveld, 1988, Ref [32]) and from *Lichens/Mosses Life Forms*.

The full definitions and guidelines for application can be found in Appendix A and in the Glossary of the software.

Cover can be considered as the presence of a particular area of the ground, substrate or water surface covered by a layer of plants considered at the greatest horizontal perimeter level of each plant in the layer (according to Eiten, 1968). A distinction is made between Closed (>60–70 percent), Open (between 60–70 and 10–20 percent) and Sparse (<10–20 percent but >1 percent). As herbaceous plants are seasonal in character, cover is always assessed in terms of fullest development.

The reason for expressing cover in terms of ranges instead of absolute values is discussed in the relevant guidelines of the software program and in Appendix A.

6.7.1.2.2 Height

The *Height* of a certain layer is measured from the ground to the average top of the life form that is being examined (Kuechler and Zonneveld, 1988, Ref [32]). The fact that single plants of one synusia differ from the average height can be ignored, apart from the fact that they can form their own layer (e.g. the emergents of a rainforest that tower above the rest). The *Height* is classed as: Trees >30–3 m; Shrubs 3–0.3 m; and Herbaceous 3–0.03 m. Each class can be further subdivided.

The major *Height* classes are linked to the Life Form selected. These classes provide general information regarding height because, in the concept of the classification, this criterion has not been given a prevalent importance. The user can choose to remain at this generic level or to go to the modifiers, whereupon the importance of height increases.

In the case of *Shrubs* or *Herbaceous* (Forbs or Graminoids) life forms, it is strongly recommended not to remain at the level of the standard definition of *Height*, if this is possible, but instead to select one of the modifiers. The ecological significance of these life forms can be strongly correlated with height (e.g. separation between low and tall herbs or between dwarf and high shrubs is important when considering the potential for grazing/rangeland).

6.7.1.2.3 Spatial Distribution or Macropattern

The next classifier that can be applied is the *Macropattern*. It is defined as *the horizontal spatial distribution of vegetation in a certain area*. It should not be confused with *Cover* because that defines the spatial arrangement of Life Forms (e.g. trees, shrubs, etc.). Macropattern describes the spatial arrangement of specific structural vegetation types (e.g. *Closed Forest, Closed Shru*bs). This classifier may seem unusual, but there are good reasons for having it:

- Often the *Macropattern* reflects an ecological or an evolutionary aspect of vegetation (e.g. scattered vegetation in arid areas; agricultural encroachment inside forest areas; degradation due to overgrazing). In many classifications, one finds terms that are extremely subjective, like “Degraded Forest” or similar. The

present classification aims to be neutral in its land cover description and avoids ambiguous terminology. Therefore *Macropattern* is used as a neutral classifier to describe vegetation status;
- this classification has been built up for mapping purposes, therefore spatial distribution of land cover is an important aspect; and
- macropattern is easily detectable from remote sensing data (photographs and imagery), i.e. it has good "mappability."

Macropattern should thus be used to give supplementary ecological information (or to show a human-induced degradational aspect of natural vegetation).

Macropattern is a concept closely linked with scale, therefore its inclusion in a classification system (that should consider only scale-independent parameters) can introduce ambiguities in application. In addition it is relevant for a very specialized group of users (vegetation ecologists), who are more familiar with this concept.

For these reasons, in version 2 of LCCS, Macropattern is not an active part of the classifiers sequence and can only be utilized after the activation of the specific button.

The combinations between *Cover* and *Macropattern* are unrestricted (this is nevertheless only valid for *Closed* and/or *Open Cover*, as will be explained later), which means that, for instance, a Closed Tree formation (Closed Forest) can be either *Continuous* or *Fragmented* depending on its spatial distribution in the mapping unit.

Due to this dimensional aspect, *Macropattern* is linked with the mapping scale. This may seem to contradict the main classification concept explained above, namely that the elements of a classification system must be scale independent. To determine *Macropattern*, one should refer to the overall appearance of vegetation formation in a certain area in a homogeneous landscape. However, if one wants to be more precise or objective in the application of this classifier, some specific rules are given below to help to standardize the interpretation. Since we are dealing with the practical application of this concept in a cartographic context, the concepts of cartographic mixed units and minimum mappable areas will be used. These concepts are further described in Section 3.8.

A certain structural vegetation type has a continuous *Macropattern* if, inside the minimum mappable area, it covers more than 80 percent of the area.

A particular structural vegetation type would be considered a Fragmented *Macropattern* if, inside the minimum mappable area, it covers more than 20 percent but less than 80 percent. This situation is linked with the mixed-unit concept. Three cases are possible:

- The structural vegetation type (e.g. dense forest) covers more than 50 percent of the area and the other element (e.g. agricultural fields) covers less than 50 percent but more than 20 percent. In this case the resulting unit will be a mixed unit with the fragmented dense forest as the dominant class (e.g. fragmented dense forest/agricultural fields).
- The structural vegetation type (e.g. dense forest) covers less than 50 percent but more than 20 percent of the area. The other element (e.g. agricultural fields) covers more than 50 percent. In this case the class is also mixed, but the dominant class will be the agricultural fields (i.e. agricultural fields/fragmented dense forest).
- When a unit contains three elements (e.g. fragmented dense forest, agricultural fields and bare areas) the rules for mixed units should be applied (see Section 3.8). In this case it could be possible to have a structural vegetation type with a Fragmented *Macropattern* as single unit. For example, fragmented dense forest, 70 percent; agricultural fields, 15 percent; and bare areas, 15 percent. As neither of the subsidiary elements reaches a cover exceeding 20 percent, the unit must be considered a single mapping unit of fragmented dense forest. This is the only case when a structural vegetation type with Fragmented *Macropattern* must be considered as a single mapping unit. Even if theoretically possible, this case must be considered as very unusual and therefore be avoided.

The *Continuous* or *Fragmented* classifiers are linked with the Cover, *Closed* or *Open* (e.g. Closed Continuous Forest, Closed Fragmented Forest, Continuous Woodland or Fragmented Woodland). Fragmentation can be further subdivided into *Striped* or *Cellular* (e.g. the tiger bush in the Sahel, where Closed Shrubs are present in the inter-dunal areas, which can be represented as Fragmented (Striped) Closed Shrubs).

The *Parklike Patches* Macropattern is directly linked with the cover category *Sparse*. In effect, this is simply redundant information. When the user defines the cover of a certain life form to be Sparse, the only Macropattern available for this structural vegetation type is Parklike Patches.

The Macropattern concept is preferentially used for Woody Life Forms (Trees, Shrubs). Herbaceous Life Forms (Graminoids, Forbs) can have a Macropattern, but this is subordinated to the absence of Woody Life Forms. When linear patches of dense shrubs (typical of tiger bush) are present together with dense herbaceous vegetation filling the space between patches, one could have two different perspectives of this situation, either *Fragmented Shrubs/Herbaceous* or *Fragmented Herbaceous/Shrubs*. In the application of the Macropattern, the rule obliges the user to always give preference to the Woody Life Form component. Macropattern can be applied to Herbaceous Life Forms only when there is no significant presence of Woody Life Forms (Trees, Shrubs). For instance, patches of dense herbaceous vegetation in sandy areas can be called fragmented herbaceous/sand.

A structural vegetation type is *Fragmented* when the sizes of the patches of the vegetation are between 1/15 and 1/2 of the minimum mappable unit. This rule is a very artificial one and should not be rigidly applied. Nevertheless, the rule assists the user by providing some reference indicator of what a Fragmented Macropattern should look like. If the patches become too small, at a certain level they could coincide with the life form itself, thus contradicting the basic rule explained above, namely that Macropattern describes the specific arrangement of structural vegetation types and must not be confused with the cover of the life form.

If all the above-mentioned classifiers are determined, the user can enter the next level and add a new set of information.

6.7.1.2.4 Water Seasonality

For Aquatic or Regularly Flooded Natural and Semi-Natural Vegetation (A24), the second level classifier consists of *Water Seasonality*. This classifier type can be described as the persistence of the water at or near the surface. There are three subdivisions:

- *(Semi-)Permanent* (three months a year or more than a specific season);
- *Temporary* or *Seasonal* (less than three months a year or during a specific season), and
- *Waterlogged*.

6.7.1.2.5 Leaf Type and Leaf Phenology

This level consists of the classifiers *Leaf Type* and *Leaf Phenology*. This option is included to allow user to opt for a basic physiognomic-structural vegetation classification but this option can be skipped if preferred. The choice of the dominant *Life Form* will deactivate a number of choices at this level as a consequence of the conditions of the classification.

The classifier Leaf Type is subdivided into:

- *Broadleaved*: referring to trees and shrubs of the botanical group *Angiospermae*, with the exception of ginkgo (*Ginkgo biloba*), that is broadleaved but belongs to the *Gymnospermae* taxonomically.
- *Needleleaved*: referring to trees and shrubs of the botanical group Gymnospermae (Ford-Robertson, 1971) carrying typical needle-shaped leaves. Note that this category includes all plants with needle-like leaves, even though they are not conifers.
- *Aphyllous*: this category encompasses plants without any leaves and plants which apparently do not have leaves in the common sense. In the first case, photosynthesis takes place through other organs, such as stems, branches and twigs; in the latter case the leaves are very short-lived or extremely reduced to scales and thorns.

Leaf Phenology is determined from the general behaviour of woody plants throughout the year. A distinction is made between evergreen and deciduous:

- Evergreen: perennial plants that are never entirely without green foliage (Ford- Robertson, 1971).
- Deciduous: perennial plants that are leafless for a certain period during the year (Ford-Robertson, 1971). Leaf shedding usually takes place simultaneously and in connection with the unfavourable season (UNESCO, 1973, Ref [45]).

The modifiers Semi-Deciduous, Semi-Evergreen and Mixed, as well as Perennial and Annual, are explained in the Glossary.

6.7.1.2.6 Stratification or Layering

The user can describe up to three layers of stratification (including the main layer) for *Terrestrial Vegetation* (A12) and *Aquatic* or *Regularly Flooded Vegetation* (A24), see Appendix B for details. The users may be disappointed by the limited number of layers at their disposal, but the classifier *Stratification* should contribute to the structural definition of a vegetation class. This means that this classifier must cover all the possible combinations with the main Life Form selected and its Cover (e.g. if we can have layering for Closed Trees, the same must be valid for Closed or Open Shrubs or Closed Graminoids, etc.). The layering is an active component of the class set-up; it is not a mere descriptive (optional and unsystematic) item of the class. The proposed classification allows the user to first build up a land cover class with the use of the classifier *Stratification* and, where more detail is wanted, add a user's description to the standard one, which may contain information on any additional layers/strata.

Some limitations in the use of the classifier *Stratification* have been introduced in order to avoid irrelevant (from the structural point of view) class combinations. The following examples will further clarify this concept:

- "Tree Savannah" is clearly defined by two main elements: a Herbaceous vegetation layer and a Sparse Trees layer. Thus, the Stratification of the two elements Herbaceous and Tree layer is crucial for the definition of this class.
- "Closed Forest" is clearly defined by the element of a Closed Tree layer. Limitations have been introduced (as will be explained below) for this class in the use of Stratification. It is not possible, in this case, to determine the presence of a Herbaceous layer because the classification rules set up for the Layering allow the user only to determine sub-layers of Trees and/or Shrubs. The determination of a Herbaceous layer would not contribute to the main structural meaning of the class as defined at the first level. The element Herbaceous layer can be added as part of the user-defined description of the class.

The limitations introduced, as shown in the two examples above, are to avoid introducing elements not crucial for the determination of the structural aspects of a land cover class. These elements can be added in the class description in the Legend. These limitations have the practical purpose of reducing the number of possible combinations of classifiers, which otherwise could lead to the creation of an even larger number of classes that would ALL have the same structural meaning.

From the practical point of view in the use of the Stratification concept, it is important to recognize that two possible types of Stratification exist:

- where the second stratum consists of the *same* Life Form as the main stratum (e.g. trees-trees and shrubs-shrubs); and
- where the second stratum consists of a *different* Life Form (e.g. trees-shrubs).

The second case is quite straightforward and does not present any difficulty in the selection of classifiers. The first case needs additional explanation. In the case of a dominant Life Form of Trees with a second stratum of Trees, it is important that these layers are clearly distinguishable one from the other (e.g. a second stratum *of Trees*

Emergent over a *Closed Tree* canopy, where these emergents must not be part of the discontinuity of the Closed Tree canopy but clearly a distinct layer). The sub-condition of *Height* will pre-set the available choices of Height for second and/or third layers/strata. For example, with a main stratum of *Closed Low Trees* (3–7 m), the emergents to be defined in the second stratum cannot have the same height (option 3–7 m therefore not available) because the *Sparse Trees* of the second layer have to be taller.

The *Height* parameter explained above depends on the Height value chosen for the main stratum; it is not applied if the general Height class is selected. If the user selects the general Height class for the main stratum, then for subsequent strata the general Height classes are the only options available.

The main conditions applied for Stratification/Layering are the following:

- Forbs and Graminoids are considered always together as Herbaceous.
- For Trees, three strata including the main, can be considered (e.g. a main Closed Tree layer with a second lower Closed to Open Tree layer and a third Sparse Tree layer of emergents is called a “Multi-Layered Forest With Emergents”).
- When the main stratum is Closed Trees or Open Trees and there is a second layer of Sparse Trees then the Height of the second layer must be higher, i.e. emergent. If they are lower they are not considered as an independent stratum.
- For Shrubs the number of strata with the same Life Form is two, including the main strata.
- For Herbaceous, only one stratum is possible.
- If the main stratum is Trees and the Cover is Open, then it is impossible to have the
- same Life Form with Cover Open To Closed with a different height as a second stratum (e.g. Open High Trees with Open Low Trees is impossible).
- If the main stratum is Shrubs and the Cover is Closed or Open with the general option of Height, then it is impossible to have the same Life Form with Cover Open To Closed with a different height as a second stratum (e.g. Open High Shrubs with Closed To Open Low Shrubs is impossible). The only exception to this rule is when the second stratum consists of Dwarf Shrubs.

These operate in combination with:

- If the cover of the main stratum is Closed Trees or Closed Shrubs, then none of the Herbaceous layers are considered or described (this can be added as a user-defined description).
- Sparse Herbaceous is never considered as a second layer except when the main layer is Sparse Trees or Sparse Shrubs (but it can be added as user-defined description).
- If the main stratum is Shrubs or Herbaceous, only one layer of trees can be considered. This is linked to the criterion of dominance, as described earlier, because the Trees or Shrubs can only be Sparse.
- Only two layers other than the main layer are considered both for Terrestrial Vegetation (A12) and for Aquatic or Regularly Flooded Vegetation (A24).

6.7.2 Cultivated and Managed Terrestrial Areas (A11 and A23)

6.7.2.1 General

In existing approaches, cultivated areas are often only described and classified by determining the crop species, the cultural practices and, in some cases, land tenure information. This may result in descriptions like “rainfed agricultural area” or “state-owned rubber plantation.” These descriptions are highly sectoral and do not address the needs of a wide variety of end-users. Another important aspect is that the principle of having a high level of geographical accuracy is frequently lacking in the sectoral approaches.

Description of agricultural areas in land cover terms should be exhaustive and neutral so that the results can be used by a broad user community. Furthermore, these areas are Primarily Vegetated land cover types, thus their description should have a link to (Semi-)Natural Vegetated land cover types at a certain level of detail, e.g. a user interested in trees because of the nesting prospects of a certain bird may not be directly interested in knowing if these trees are part of a crop or (Semi-)Natural Vegetation. Furthermore, the focus should be on the definition of geographically well-defined classes, i.e. classes having a high mappability.

Therefore, the approach taken in order to enable a wide variety of users to employ the descriptions of cultivated areas is that of a basically physiognomic-structural classification. This means that at a high level of classification the cultivated area description is based on the structure of the vegetation, whereas at lower levels, with lower mappability, the focus is on description of the spatial and temporal dimensions. This type of description should, however, assure a high degree of compatibility with existing agricultural classification systems. This means that not only should the classes be compatible, but also should the methods of deriving classes and their spatial and temporal dimensions (Duhamel, 1995). The spatial and temporal dimensions for cultivated areas clearly differ from (Semi-)Natural Vegetation, as in most cases there is a constant flux in the observable cover.

Owing to this flux, the moment of observation of the land cover is very important, as the land might be ploughed, sown or harvested (with no crop actually visible) or a crop is clearly visible and different crop growth stages can be identified. These temporal dimensions influence the land cover but should not influence its description, because the area should be classified independent of the time of observation. It is for this reason that in the definition of *Cultivated Areas* provision is made for the fact that vegetative cover is not always present.

In the structural approach, physiognomy or Life Form is the principal classification criterion, followed by the vertical structure, the crop layering and horizontal structure, i.e. the Field Macropattern, of the area. This will result in detailed cover information that can be optionally combined with *Crop Type* as a specific technical attribute to establish the link with many current classification systems.

In the major land cover type of *Terrestrial Cultivated Areas* and *Managed Lands* (A11), Managed Lands form a separate category. They comprise land cover classes that are clearly vegetated and managed, though not with the intent of harvesting as is the case for *Cultivated Areas*. The structural description of their cover in this classification may appear simplistic, but a further description in land use terms would not render much more information. The description in cover terms will assure a high level of mappability, which can be freely combined with user-defined land use descriptors.

6.7.2.2 Life Form – Managed Lands

Managed Lands form a separate category inside the *Cultivated Terrestrial Areas and Managed Lands* (A11) and consist of one single classifier: Life Form. The Managed Land Areas are described by the Life Form composition rather than description of the individual Life Forms of the vegetation. They are defined by specifying the occurrence of trees, shrubs and/or herbaceous life forms. Three options are available: *Parklands, Parks* or *Lawns*. Managed Lands may comprise private gardens, public green areas, sport fields, etc. They are usually found in the (peri-)urban environment. This category may be further elaborated in future to include a wider range of classifiers for more detailed descriptions.

6.7.2.3 Life Form – Cultivated Areas

Two main aspects of the classifier Life Form should be taken into account:

- the concept of Life Form in this classification; and
- determination of the dominant Life Form.

Careful determination of these two main aspects is important because the classification is set up in such a way that the choice of the main Life Form has consequences for the choices available at lower levels due to certain built-in conditions.

Life Form is defined by the physiognomy of the plants. Under *Cultivated Terrestrial Areas*, Trees and Shrubs are distinguished from Herbaceous plants, subdivided into Forbs or Graminoids. *Under Cultivated Aquatic or Regularly Flooded Areas*, only *Graminoid* and Non-Graminoid crops are distinguished. The following rule applies: those plants that belong to the *Graminaceae* family but have a woody appearance (e.g. bamboos) are classified as

Herbaceous plants. This rule differs from the rules applied in Natural and Semi-Natural Vegetation (major land cover types A12 and A24).

For determination of dominance the following rules apply:

- The main criterion is the uppermost canopy layer. This means that the cover goes from Trees to Shrubs to Herbaceous/Forbs/Graminoids.
- This general condition is subject to a sub-condition of "marginality", i.e. the crop should cover at least 15 percent of the area and/or should return the highest economic revenue.

These two rules are the main criteria for determining the main crop. There are no restrictions to possible crop Life Form combinations (in contrast to (Semi-)Natural Vegetation, as explained in the next section).

The *Trees* and *Shrubs* Life Forms can have two additional modifiers: Leaf Type (*Broadleaved* or *Needleleaved*), in combination with Leaf Phenology (*Evergreen* or *Deciduous*). The introduction of this modifier for these two Life Forms assures a link with the description of the natural vegetated areas.

6.7.2.4 Spatial Aspect – Size and Distribution

The second classifier that can be applied is *Spatial Aspect – Size*. This classifier often implies other aspects (e.g. land tenure, mechanization, land reclamation, etc.). "Large-scale irrigated agriculture" or similar terms are common in many classifications systems. This classification needs to be neutral in its land cover description without including ambiguous terminology. Therefore, *Spatial Aspect* has been selected as a neutral classifier. For mapping exercises, Spatial Aspect is an important aspect at the meso- or macro-level. Furthermore, it is an easily detectable characteristic (e.g. on aerial photographs and satellite imagery), i.e. it has good "mappability."

The Field Size classifier is applicable at the level of the individual field and has three categories:

- less than 2 ha;
- 2 to 5 ha; and
- more than 5 ha.

This classifier can be skipped because size is a very subjective parameter. *Spatial Distribution* is the horizontal pattern of cultivated fields in a certain area. It can be easily measured, taking the distance between one field and the next. A distinction has been made into three classes:

- *Continuous* describes a continuum of more than 50 percent of cultivated fields. In this case the land cover mapping unit may be single (inside the mapping unit the fields take up more than 80 percent) or mixed (the fields occupy 51–80 percent of the mapping unit). Generally, when the fields occupy 51–80 percent of the mapping unit, the area in between the fields can be considered by the user as part of the cultivated area or the user can decide to make a mixed mapping unit, depending upon which land cover features the user wants to highlight.
- The Spatial Distribution is *Scattered Clustered* or *Scattered Isolated* when, within the cultivated field area, other land cover types are present. They are defined as follows:
  - - If the percentage of fields is more than 20 percent but less than 50 percent, it is *Scattered Clustered*: this means that the resulting mapping unit is a mixed land cover class of a cultivated area with another subordinate land cover class and both components need to be defined in the legend (e.g. 40 percent of fields and 60 percent of semi-natural vegetation).
  - - If the percentage of fields is more than 10 percent but less than 20 percent it is considered *Scattered Isolated*. This means that the resulting mapping unit is a mixed land cover class where the dominant class is not this one. It is the only case where a class comprising less than 20 percent is present in a mixed mapping unit (see Section 3.8).

6.7.2.5 Crop Combination (only for A11)

At the second level, the *Crop Combination* is specified for the Cultivated Terrestrial Areas. If there is more than one crop, the crops present can be specified together with details of the possible overlap in growing period between the main and secondary crops. The order in which an additional crop is specified follows the same condition as stated above.

- The dominance is determined by the **main criterion of the second-uppermost canopy layer**. This means that the cover goes from Trees to Shrubs to Herbaceous/Forbs/ Graminoids.
- This general condition is subject to a **sub-condition of margina**lity i.e. the crop should cover at least 15 percent of the area (but less than the main crop) and/or should return the second highest economic revenue. It is important to note that the second-level classifier *Crop Combination* can also be skipped by the user because of the apparent difficulty in determining the classifiers correctly. This skip function will then permit the user to continue the description of the main crop at the third level.

6.7.2.6 Water Seasonality (only for A23)

The second level classifier *Water Seasonality* of Aquatic or Regularly Flooded Cultivated Areas describes the duration of water on or near the surface during the main crop cultivation period. If any additional crops are cultivated after or in overlap with the main crop, the period of water at or near the surface for these crops should be neglected.

6.7.2.7 Cover-Related Cultural Practices – Water Supply and Cultivation Time Factor (A11)

At the third level of classification, the classifier *Cover-Related Cultural Practices – Water Supply* is determined. The options *Rainfed Agriculture, Post Flooding* and *Irrigated Agriculture* for Cultivated Terrestrial Areas have implications for the options available under *Cultivation Time Factor. Post Flooding* cultural practices are not possible in a *Permanent Cultivation* system. It is also obvious that the dominant crop determined will have implications for other classifiers (e.g. a Tree Crop will result in a Permanent Cultivation system).

A Permanent Cultivation system in combination with either a Trees or Shrubs Life Form designates what is commonly known as plantations and orchards (e.g. a forest plantation or a coffee plantation). However, these names do not occur *per se* in this classification system. In combination with Crop Type, a link to current systems can be made and to commonly used names such as “plantation” (e.g. the combination of Shrub Crop and *Crop Type: Tea* covers “Tea Plantation,” while *Tree Crop* and *Crop Type: Hevea spp*. refers to “Rubber Plantation”).

6.7.2.8 Cover-Related Cultural Practices – Fallow Period (only for A23)

Cover-Related Cultural Practices – Fallow Period is the third-level classifier for Aquatic or Regularly Flooded Cultivated Areas. It has three subdivisions: *Permanent; Relay Intercropping*; and *Sequential*. They are, however, defined differently from Cultivated Terrestrial Areas because they refer to the practices that occur after harvest of the main aquatic crop. These practices may not relate to the same Aquatic or Regularly Flooded environment of the main crop.

6.8 Classification concepts for primarily non-vegetated areas

6.8.1 General non-vegetated areas

Areas primarily characterized by a cover other than vegetation fall into two categories: those with a non-vegetal cover and those with no cover at all. The latter is a category that describes the land surface rather than any cover of the land but which has been included here, as explained earlier (see Section 2.1).

The approach adopted for describing *Primarily Non-Vegetated Areas* is, as for Vegetated Classes, a “structural-physiognomic” approach, i.e. the physiognomy, the cover (i.e. density) and structure are used as parameters. The classifiers Surface Aspect (Artificial Surfaces and Bare Areas) *and Physical Status (Artificial and Natural*

Waterbodies, Snow and Ice) can be regarded as descriptors of the physiognomy of the materials, like Life Form for vegetation. The further classifiers and modifiers of Bare Areas and Artificial Surfaces contain elements of *Cover*, as for Terrestrial Vegetation, whereas the *Water Persistence* classifier is similar to Water Seasonality in Aquatic Vegetation.

6.8.2 Artificial Surfaces and Associated Areas (B15)

6.8.2.1 General Artificial Surfaces

Areas with an artificial cover resulting from human activities are described in most classification systems in terms of use, whereas the description of cover is equally important. An example is urban areas where the surface generally consists of impervious materials. This type of surface greatly influences run-off and the peak flow characteristics of water. Another example is tarmac roads in hilly terrain, where road constructors need to carefully plan for the discharge of excess water that, in poor designs, may lead to disastrous forms of erosion.

The Associated Areas are mainly domains where the original surface is removed, such as extraction sites, or where materials have been deposited on top of the original surface, such as waste dumps and other type of deposits.

The characteristics of the cover of the surface are crucial in the land cover description and therefore embody the main classification concept. This major land cover type is classified depending upon the Surface Aspect. A category for the Built-Up Object can be specified using the scroll list (e.g. cities and towns, roads, open mines, official waste dump sites, etc.).

6.8.2.2 Surface Aspect

The *Surface Aspect* distinguishes two main classes, with one class having two levels with an increase in detail. A much more detailed class description can be made using the modifier options. These modifiers are explained in terms of cover rather than land use terminology.

The *Artificial Surface* areas can be further defined according to the shape and density of the artefacts.

6.8.3 Bare Areas (B16)

6.8.3.1 General Bare Areas

Areas that are primarily bare are usually described by geologists, soil scientists or geomorphologists (using technical terms like granite rock, rendzhina, sand dunes, inselberg, tor, etc.). This type of description is highly technical and may be difficult to understand for users with a different background. A different approach is therefore needed in the context of this classification scheme for describing the type of material on the surface, with additional options to go into more detail, in combination with elements describing either some specific properties (physical or chemical) of the surface material or describing some specific forms. Specific forms implies that the surface may consist of shapes that form a pattern at the macro-level. The focus of the cover description is on the surface and not on the subsoil.

The major land cover type *Bare Areas* is therefore described mainly by the appearance of the surface. The concept adopted describes the aspects of the cover: whether it is consolidated or not, what kind of material it consists of (e.g. rock, sand) and which may be combined with Macropattern. The more discipline-related descriptors for geology, landform and soil are available as attributes and can be used to link the land cover description to the technical disciplines.

6.8.3.2 Surface Aspect

The *Surface Aspect* describes the surface of the Bare Area at two levels, with an increase in detail. A further specification can be made by using one of the modifiers. These modifiers specify some physical or chemical properties.

6.8.3.3 Macropattern

The *Macropattern* describes the pattern of the surface. This classifier is linked to the *Surface Aspect* because a *Macropattern* can only be of the same material as the surface described. Hence the choice made under *Surface Aspect* may disable certain choices in this classifier. Two types are distinguished, namely *Bare Soil* and *Loose and/or Shifting Sands*.

6.8.4 Artificial and Natural Waterbodies, Snow and Ice (B27 and B28)

6.8.4.1 General Artificial and Natural Waterbodies, Snow and Ice

The two major land cover types describing water surfaces or other physical appearances of water*, Artificial Waterbodies, Snow and Ice* (B27) and *Natural Waterbodies, Snow and Ice* (B28) are described by taking into account their temporal aspect. Water, snow and ice may not be present all year round and therefore it is also important to know what the cover is when they are absent. This temporal aspect should not influence the classification results because classification by default is independent of temporal change.

In most existing classification systems these land cover types are only briefly described in terms of cover, with no additional information. The concept adopted by this classification puts more emphasis on the temporal aspect.

The major difference between these two major classes is that *Artificial Waterbodies, Snow and Ice* are surfaces in places where, under natural circumstances, no water, snow or ice surface would exist. Therefore these surfaces are the result of an artefact, such as the construction of a dam, artificial snow or ice-making.

6.8.4.2 Physical Status

The Physical Status describes in which form water is found. Three options are available: Water, Snow or Ice. Depending on the choice made here, other classifiers at lower levels may be disabled. For water and ice a further specification can be made into Flowing or Standing Water and Moving or Stationary Ice.

6.8.4.3 Persistence

Persistence, i.e. the duration that Water, Snow or Ice covers the surface, is described. If Water, Snow or Ice is present for nine months or less per year, the surface then exposed can be further specified.

6.8.4.4 Depth

The *Depth* can be described because it is directly related to cover aspects. The proposed classifier has not been given a lot of detail because the most important feature to be determined is whether it is deep or not, i.e. whether it is shallower or deeper than 2 m. This limit has an ecological meaning as it is the maximum rooting depth for the great majority of aquatic plants (Cowardin et al., 1979, Ref [9]).

6.8.5 Sediment Load

The suspended *Sediment Load* in the water influences the cover and implies other environmental aspects, such as upstream erosion and downstream sedimentation. It also influences the aquatic fauna and flora. It is a relatively easily observed characteristic of the water, but difficult to measure as it fluctuates. Therefore the subdivision has not been given great detail.

6.9 Environmental and specific technical attributes

6.9.1 General environmental and specific technical attributes

The pure land cover classifiers can be combined with so-called attributes for further definition of the land cover class. Two types of attributes are distinguished, forming distinct levels in the classification:

- Environmental Attributes: attributes that are not inherent features of land cover but may influence the land cover.
- Specific Technical Attributes: attributes referring to the technical discipline of the major land cover type.

6.9.2 Environmental Attributes

6.9.2.1 Landform

Land forms are described first and foremost by their morphology and not by their genetic origin or the processes responsible for their shape. The dominant slope is the most important differentiating criterion, followed by relief intensity. This attribute can be applied to all classes except Artificial Surfaces and Artificial and Natural Waterbodies, Snow and Ice. The attribute consists of two different levels, i.e. major land form and slope class according to the Soils and Terrain (SOTER) methodology (UNEP/ISSS/ISRIC/FAO, 1995, Ref [44]).

6.9.2.2 Lithology

The lithology can be described based on the geological parent material and its age. The options have been provided by S.B. Kroonenberg (personnel communication, 1998). Three major groupings are distinguished and further subdivided. The classifiers used for subdivision are described in the registery of classifiers.

6.9.2.3 Soils

For the *Primarily Vegetated Areas*, the user can describe first the soil's Surface Aspect, followed by a detailed description of the soil profile according to the Revised Soil Legend (FAO, 1988, Ref [23]). For Bare Areas (B16) only the soil profile description is applicable because the soil surface aspect is a classifier of this major land cover type.

6.9.2.4 Climate

The concept adopted to add climatic parameters to the land cover classes is from De Pauw, Nachtergaele and Antoine, 1996, Ref [12], whose revised Length of Growing Period (LGP) approach gives recognition to the relevant climatic constraints in any major region of the world. The combination of Thermal Classes and Moisture Classes gives the climate. No conditions have been pre-set.

6.9.2.5 Altitude

This attribute can be used in all major land cover types. The classes of this attribute are a proposal and can be further subdivided by using the possibility available in the Legend Module to create a user-defined attribute.

6.9.2.6 Erosion

In the description of *Erosion* in the land cover, emphasis is given to accelerated or humaninduced erosion. Human-induced erosion is often the result of irrational use and poor management, such as incorrect agricultural practices, overgrazing or overexploitation of the (semi-)natural vegetation. These practices result in a cover type with specific features. Most of the erosion can be classified as either Water or Wind erosion and deposition, with Mass Movements as a third major category. Further subdivision can be made by using the User-defined Attribute option in the Legend Module. This attribute is applicable in all *Primarily Vegetated Areas and Bare Areas* (B16).

6.9.2.7 Water Quality (only for A24)

This attribute is only applicable in *(Semi-)Natural Aquatic or Regularly Flooded Terrestrial Areas* (A24). It can be used to specify the salinity of the water, which is measured in ppm of total dissolved solids (TDS) according to Cowardin et al. (1979), Ref [9].

6.9.2.8 Vegetation (only for B16, B27 and B28)

This attribute is applicable for *Bare Areas* and *Artificial and Natural Waterbodies, Snow and Ice* (e.g. sandy riverbed with scattered vegetation) to indicate that less than 4 percent of vegetation is present. In the case of the presence of Lichens and/or Mosses, they should be less than 20 percent of the total mapped).

6.9.2.9 Cover/Crop Density (only for A11 and A23)

This attribute is only applicable for the *Cultivated Areas*, both *Terrestrial and Aquatic or Regularly Flooded*. This attribute gives information on the density of the permanent crops, (e.g. Trees and Shrubs) or the cover of the temporary life forms (e.g. Herbaceous, Forbs and Graminoids). This information is an indicator of the success of crop establishment and hence its possible yield.

Density has not been used as a land cover classifier, as for *(Semi-)Natural Vegetated Areas*, because it normally would not add any useful information to the land cover class. The density is related to the planting distance of the crop, which differs according to crop (e.g. olive trees versus maize). However, it is a useful attribute when describing a cultivated area that does not have the expected density of the crop (e.g. in marginal areas).

6.9.3 Specific Technical Attributes

6.9.3.1 General information - Specific Technical Attributes

These attributes are related to the technical discipline associated with the major land cover types. Thus, for (Semi-) Natural Vegetated areas, the Floristic Aspect can be described; for Bare Areas, the Soil Type (as discussed under *Soils*); for Cultivated Areas, the Crop Types; and the Salinity for Artificial and Natural Waterbodies, Snow and Ice.

6.9.3.2 Crop Type (only for A11 and A23)

The *Crop Type* can be specified according to the major groupings used for the FAO Production Yearbooks. If a *Crop Type* is not present, it can be defined and added under the header *Other* in the boxes that open upon clicking. Furthermore, the name of the crop has to be linked to the dominant, second or third crop choices in order for the entry to be saved. A maximum of three names can be specified.

6.9.3.3 Floristic Aspect (only for A12 and A24)

This attribute has two major divisions: whether the name is derived from a single plant form or from a group of plant types. In the first option, a further subdivision is possible into *Dominant Species* (Height, Cover or combination of both) and *Most Frequent Species*. The second option is subdivided into: *Plant Groups* (e.g. Braun-Blanquet) and *Plant Groups Derived Without Statistical Methods* (e.g. same ecological significance; same geographical distribution; same dynamic significance). The specific name of the *Floristic Aspect* can be added with the User-Defined Attribute option in the Legend Module.

6.9.3.4 Salinity (only for B27 and B28)

The *Salinity* of the water can be specified for *Artificial and Natural Waterbodies*. Three main classes are distinguished, based upon Cowardin et al. (1979) Ref [9].

6.10 The advantages of the method adopted

6.10.1 Advantages from the conceptual point of view

LCCS is a real *a priori* classification system in the sense that, for the classifiers considered, it covers all their possible combinations. Some particular combinations are excluded, due to conditions that are elements of the classification system. In this case the type of combinations and the conditions, i.e. the reasons for this “exclusion” are clearly listed and explained.

A given land cover class is clearly and systematically defined, making a clear and unambiguous differentiation by use of the classifiers as follows:

- pure land cover classifiers (each one ordered from the general to a more specific level);
- environmental attributes (e.g. Climate, Landform, Geology, etc.); and
- specific technical attributes (e.g. Floristic Aspect for (Semi-)Natural Vegetation).

This system avoids unclear definitions (e.g. “tropical rain forest” where a climatic attribute is used for a floristic description).

The classification is truly hierarchical. The class’ hierarchical arrangement is a basic component of the mechanism of the class formation. The difference between a land cover class (at a more general level) and a further subdivision of it is given through the addition of new classifiers (on a more detailed level of the one forming the previous class). The more classifiers used, the greater the detail of the land cover class defined.

The classes derived from the proposed classification system are all unique and unambiguous, due to the internal consistency and systematic description of the class as a basis for objective and repeatable classification. Correlation studies between classifications show that, in many cases, definitions of the class names are often either unclear or unsystematic or both, due to the fact that in traditional classifications and legends the “meaning” of a class is derived only from its general description. Such a descriptive text is very often unsystematic and, as a result, in many cases there are insufficient details to define strict boundary conditions. The classes are therefore open to misinterpretation and lack internal consistency. With the present classification, the user’s primary descriptive tool is the Boolean Formula of all classifiers used to build the class; this cannot be anything other than a systematic description of the class. In addition to this, the traditional class description is used. A strict class boundary definition and internal class consistency are inherent in the method.

LCCS is designed to map at a variety of scales, from small to large.

For two main reasons, the classification can be used as reference classification:

- the classification contains a large number of classes (the classes of the existing classifications and legends can always be accommodated); and

- emphasis is on a set of classifiers rather than just a name, which allows easy correlation even when a range of values, such as the percent of cover of a given life form, does not fit with the proposed value; the dissimilarity is clear and remains limited to only a portion of the elements forming the class. This event however should be extremely rare due to the different levels, from more general to more specific, forming a single type of classifier.

6.10.2 Advantages from the practical point of view

The specific design of the classification allows easy incorporation and integration into GIS and databases. The mechanisms of how the classes are built up, as discussed earlier, facilitate overlay procedures.

It will produce a real multi-user database. Despite the high demand for natural resources information, many databases are not developed to meet multi-user requirements. This is shown by the fact that, in practice, very often the number of real users is often a small portion of the potential ones. An important cause is the inherent rigidity of the natural resources information (i.e. land cover) of the databases. Two cases are typical:

- the original project is very specialized (e.g. vegetation ecology), hence the class name and description of the resulting legend are difficult to understand by other users (such as rural planners, statisticians, etc.); or
- the original project is not specialized, so the classes or the class descriptions are too generic to be used by specialized disciplines.

The ways in which current classifications determine the classes (names and generally a broad description) do not allow a great deal of flexibility in use by the final user. The present classification system assumes two types of final users:

- the one that uses the classification to build up the database (the user basically doing the interpretation activity); and
- the one that is the final user of the database created.

The system obliges the first user (the database builder) to follow specific rules in the combination of classifiers (to assure standardization and comparability of the data set) but allows the database user to define freely the set of classifiers by which they wish to re-aggregate the original polygons of the database. Because the class definition is linked with the classifiers' Boolean Formula, this is a straightforward process. Of course, the number of potential recombination of classifiers is extremely large and some combinations may be illogical, but this respects the concept of multiple users, each with their very specific needs.

For interpretation purposes, the advantages are:

- It is highly flexible, responding not only to the information available or gathered in a given area, but also to the time and budgetary constraints of a project. This means that within one land cover map, mapping units will contain the maximum available information, but the quantity of information may differ between the mapping units. This will not affect the homogeneity of the resulting map. It will be possible, for instance, to have, within the same map in a certain geographical area, polygons of a class formed with a certain number of classifiers (a high number as more ancillary information is available), while, in another part, polygons where the same type of class will have fewer classifiers. It will always be possible to compare the two classes.
- It rationalizes the field data collection. The classes are defined by a combination of classifiers: field surveyors should detect the single classifiers and not deal with the final class name. This means that the field survey can be done independent of, or in parallel to, the interpretation process.
- It facilitates standardization of the interpretation process, contributing to its homogeneity. Despite the huge number of classes the interpreter can generate to fit the land cover variations, one is dealing only with a limited number of classifiers. So one does not need to scroll inside a big, obscure list of class names, but must simply aggregate a limited number of well-defined classifiers. This will also reduce heterogeneity among interpreters and among interpretations over time.
- It allows the building up of a new procedure of accuracy analysis of the result. Until now, accuracy analysis was done for single classes; henceforth it will be possible to assess the accuracy not only for the entire class but also for each of the classifiers forming the specific class. This will give a high flexibility to finalization of the classes. If, for instance, a class formed by five classifiers shows an accuracy of 60 percent, which is too low according to the established standard, then by looking at the individual classifiers forming this class the user can analyse the contribution of each individual classifier to the overall class accuracy. If, in the example, the first four classifiers have an accuracy of 90 percent while the fifth classifier only 60 percent, the user may decide to eliminate this last and less accurate classifier in order to have a final class with less detail but with a higher accuracy.

6.11 From classification to legend

6.11.1 General concepts

Classification is an abstract representation of the situation in the field using a particular set of diagnostic criteria, whereas a legend is the application of the classification's abstract design in a particular area using a defined mapping scale and a particular data set. This transition implies establishment of specific conditions not present in the classification concept (e.g. Minimum Mappable Area and Mixed Mapping Units). Because one of the ultimate goals of this classification is to provide a useful tool for mapping exercises, these conditions will be discussed here, even if they are not strictly appropriate to the main subject of this chapter.

6.11.2 The Minimum Mappable Area concept

The *Minimum Mappable Area* is a concept applied by cartographers when addressing the smallest area that can be shown on a map. This concept is therefore scale-dependent and not related to classification. However, the issue is addressed here as it usually presents problems.

The concept of one single mappable area is generally applied. Historically, the cartographer determined one particular minimum area to be represented on the map. This was applied to all classes contained in the legend. The disadvantage of this method is that classes with a difference in importance would follow the same rules. It would have been more logical to define a set of different sizes for the various features with differing importance (Di Gregorio, 1991, Ref [14]).

The flexibility of this current classification (LCCS2) allows the introduction of the concept of a variable minimum mappable area. Thus, the user can relate the size of the minimum mappable area to the eight major land cover types from which the classes are derived (Figure 6).

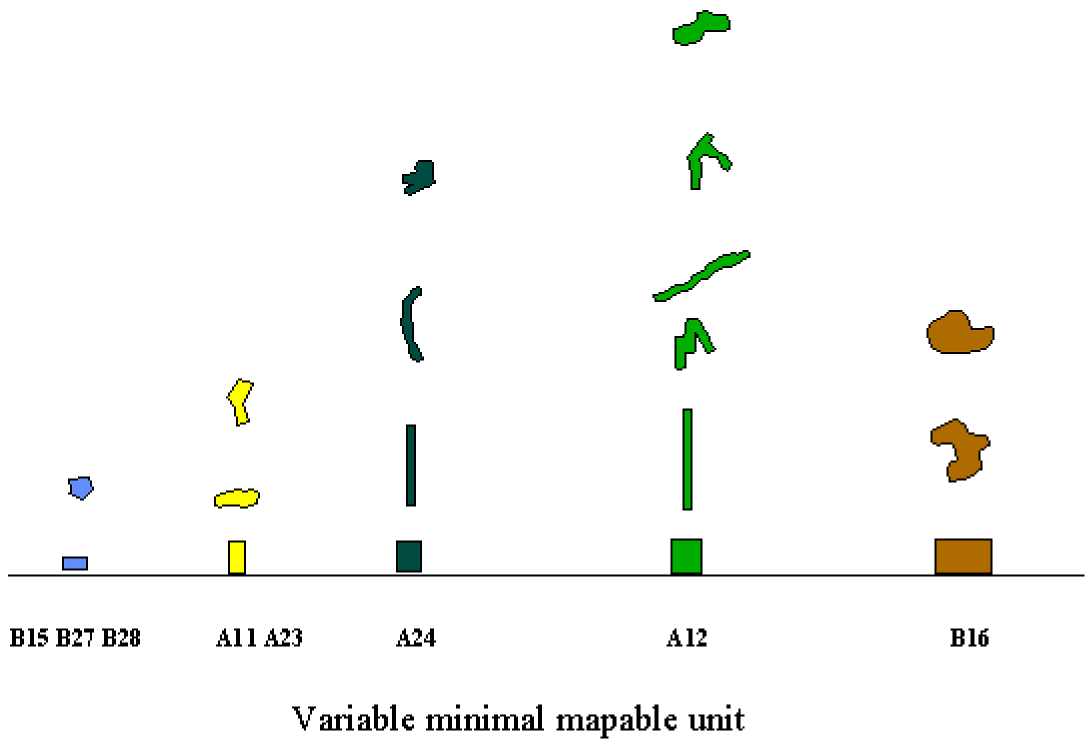

Figure 6 - Example from the East Africa Project, with variable minimum mappable areas (not at original scale)

6.11.3 The Occurrence of Mixed Mapping Units

In the classification system, all classes are unique and no Mixed Mapping code is considered. However, LCCS2 offers the possibility of generating a mixed code when saving a class from the classification to a legend. In effect, when moving from the abstract concept of the classification system to the practicalities of the field, the user has to deal with a particular legend that reflects both parameters of scale and inherent characteristics of the area. LCCS2 considers several types of mixed codings, with an exhaustive and codified syntax. Two basic types of mixed coding are present:

- thematic mixed coding; and
- spatial (with or without being time-related) mixed coding.

Thematic mixed coding relates to a thematic uncertainty. It means that the specific polygon coded with the "thematic mixed code" cannot reflect unique thematic information (written A//B, implying "equal to A OR B", where A and B are land cover classes). It needs a certain level of generalization of the information. This syntax can be used only if the internal capabilities of generalization of LCCS are inadequate. In LCCS, in fact, the user has a certain possibility of generalizing the thematic class, meaning going from a more general to a more detailed level of class definition. If, for instance, the classifier *Woody* is used, this implies that an intricate mixture of trees and shrubs is present in which neither trees nor shrubs are clearly dominant. Thematic mixed coding, then, is an extra resource for the user to further generalize the thematic meaning of a class or for acting at a single-polygon level where, due to interpretation problems, a certain level of generalization is required.

Spatial mixed coding relates to the constraint of the scale when representing a geographical feature. It means that in the specific polygon coded Spatial Mixed, all the features are present but, due to the scale constraint (Minimum Mappable Area), they cannot be represented singularly (written A/B, implying "equal to A and B").

A Spatial Mixed Mapping code is always characterized by two or three (maximum) separate single land cover classes as defined in the classification system. The conditions governing the use of mixed mapping units are that within the minimum mappable area, two or more land cover classes are present, in a spatially separate entity (e.g. patches of agricultural fields inside a forest).

In this case, the general criterion proposed is that the cover of each one of the classes considered must be more than 20 percent (and consequently less than 80 percent) of the mapping unit. The limit of 20 percent is thus the threshold of "visibility" of a class in a Spatial Mixed Unit. The only exception to this rule is in the major land cover type *Cultivated Areas*, where the use of the option *Scattered Isolated* of the classifier *Spatial Distribution* goes from 10 to 20 percent (see Section 6.7.2.4).

The sequence of the class names in a mixed mapping unit represents the dominance (e.g. for *Forest/Cultivated Areas*, Forest is more than 50 percent and less than 80 percent, whereas Cultivated Areas is less than 50 percent but more than 20 percent). A Mixed Mapping Unit can contain a maximum of three classes.

A variation of Spatial Mixed coding is the so-called "Layering". This situation applies when a feature belonging to Agricultural and Managed Area and another belonging to Natural Semi-Natural Vegetation occur in two separate strata (e.g. rainfed cultivated fields with open natural trees). For this specific case a different syntax is used (written A + B, implying "A and B layering").

A particular case is "Time-Related" Mixed coding. This applies only to classes belonging to the major land cover categories *Cultivated and Managed Terrestrial Area(s)* (A11) or *Cultivated Aquatic or Regularly Flooded Area(s)* (A23), where the syntax is "A///B", indicating "A in one year; B in the other". Such coding is used to describe the situation where, in different years, different types of cultivation occur in the same field (i.e. the mapping unit). This is the case when the user has, for example, a situation of cultivated fields of paddy rice in one year (e.g. when there is sufficient rainfall), followed by a terrestrial crop in a subsequent year (e.g. when rainfall is poor). This particular type of Time-Related Mixed coding shows often a cyclic, almost customary, alternation of different crops in subsequent years (e.g. generally an Aquatic crop followed by Terrestrial crops, or an Irrigated crop followed by Rainfed crops). It is important **to note that the alternation of crops should be considered only when this occurs on an annual basis**. The combination of different crops in the same growing period is an option already considered in LCCS class creation (see the classifiers related to Crop Combination in A11). However, because of the specific nature of this type of Mixed Unit, that occurs only where crops are growing, the classes composing such a mixed unit can only be those of Cultivated Area(s).

7 Classification Language

7.1 Introduction

The relationship between classification objects in the LCCS is defined in an algorithmetic manner by a set of rules. Classification objects are established by the definitions associated with the classifier together with rules that specify the allowable combinations of classifiers. An example of a rule is "dominance". A classification object (class[2]) called "savana" is dominant grass with sparse trees and or sparse shrub. That is, the relationship of dominance relates the grassland to its secondary cover.

There are a large number of rules in LCCS relating classifiers to each other and to external attributes such as geometry or scale. An example of this is the minimum mappable area rule which establishes the smalest area for a classification object. Since there can be very many such rules formlized method must be used to establish these rules. This formalization assists in implementing software to assist a user in developing legends and assigning identified areas to particular classifications.

The LCCS classification system is rigorously described using formal language theory terminology. Tools are available, such as the ProLog programming language Ref [8], to represent this rigorous description in a machine readable form. ProLog programming code can be used to express the relationship between classifiers and can be registered in the LCCS registry, together with definitions. Rules must be expressed as valid statements within the language used to describe rules and must be consistant with each other.

7.2 LCCS formalization

The LCCS system is described as a classification *languag*e, using formal language theory terminology and features for its representation. Land cover elements (trees, heights, roads, crop combinations, etc.) are the language *words. One defines a grammar* for LCCS to build *sentences* (classes) with these words; and finally one defines the LCCS *semantics*, to establish the set of correct sentences (i.e. the whole language).

The formalism used to express the LCCS rules is the ProLog programming language. Prolog is a logical and a declarative programming language which derives from mathematical work on the development theorem provers and other automated deduction systems. The language has been in use for over 30 years. It has been used in computational linguistics as the basis for natural language processing. It was extensively used in the fifth generation programming language efforts dating from the mid 1980s. The reference document is the textbook by Clocksin and Mellish Ref [8].

The grammar rules described in Prolog are registered as part of the LCCS register. This allows the rules to be managed and updated in the same manner as the associated registered definitions.

8 LCCS Classifier Registry

8.1 Introduction

The LCCS classification system registry is owned and maintained by the Food and Agricultural Organization of the United Nations to describe the classifiers, attributes (modifiers) and other elements of the LCCS classification system This registry is defined in accordance with the standard 19135 that describes the general requirements for a geographic information register, in accordance with ISO 191xx-1 which describes the requirements for a data dictionary register for a classification scheme and in conformance with this standard that describes the registered elements.

All classifiers and modifiers within the registers must have a unique code and alpha code.

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[2] Note that this use of the word *class* is the dictionary definition, not the specialized use in UML modeling.

8.2 LCCS Register structure

8.2.1 Structure

The schema specified in this clause describes the structure of a data dictionary register for the LCCS classification scheme. The schema consists of the elements defined in the following sub clauses together with the general schema provided in part 1 of this standard. The schema is specified in UML [ISO/IEC 19501] in conformance with ISO 19103. The schema of the LCCS data dictionary register is that of part 1 of this standard with additional detail expressed about the registered items.

8.2.2 Management of the register and registry

ISO 19135 defines a number of roles that must be handled for the management of a registry. For the LCCS register and registry the roles are the following:

Register Owner - Food and Agricultural Organization of the United Nations

Submitting Organization - UN Member bodies through the UN FAO

Control Body - LCCS management committee convened by the UN FAO SDRN

Register Magager - Environment and Natural Resource Service (SDRN) of the UN FAO

Registry Manager - Environment and Natural Resource Service (SDRN) of the UN FAO

Register Users - The register is open for access by the public in any UN Nation.

8.2.3 Elements of the registers

The data dictionary register for LCCS classification system is a compound register in which several item classes are registered. The item classes are:

- classifier - code, name, and definition
- modifiers (attributes);
- enumerant (listed) values;
- units of measure;
- rules describing the relasionship between classification or the relasionship of classification objects to geometry.

Additionally, each item also includes information necessary to manage that item, as specified in ISO 19135.

8.2.4 Registered Items

8.2.4.1 Classifier Item

This registered item describes each classifier. Each classifier must have a code, a name and a definition. Optionally the classifier may include a reference to a description of the source of the definition, a description of guidelines for use, and a reference to a list of enumerated values and units of measure that may apply to the item.

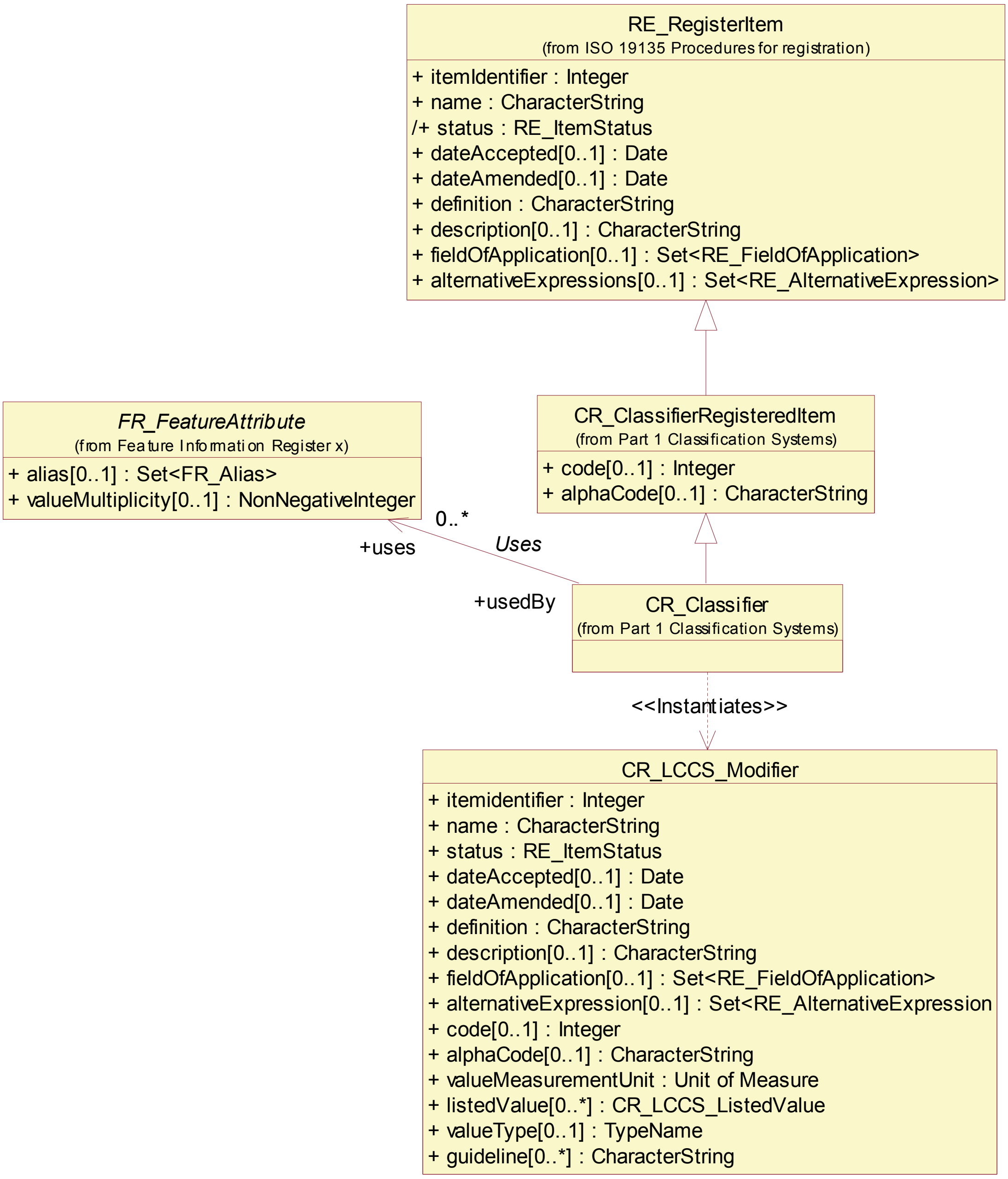

Figure 7- Classifier Registered Item

8.2.4.2 Modifier Item

This registered item describes each modifier that may be used with a classifier. Each modifier must have a code, a name and a definition. Optionally the modifier may include a reference to a list of enumerated values and units of measure that may apply to the modifier.

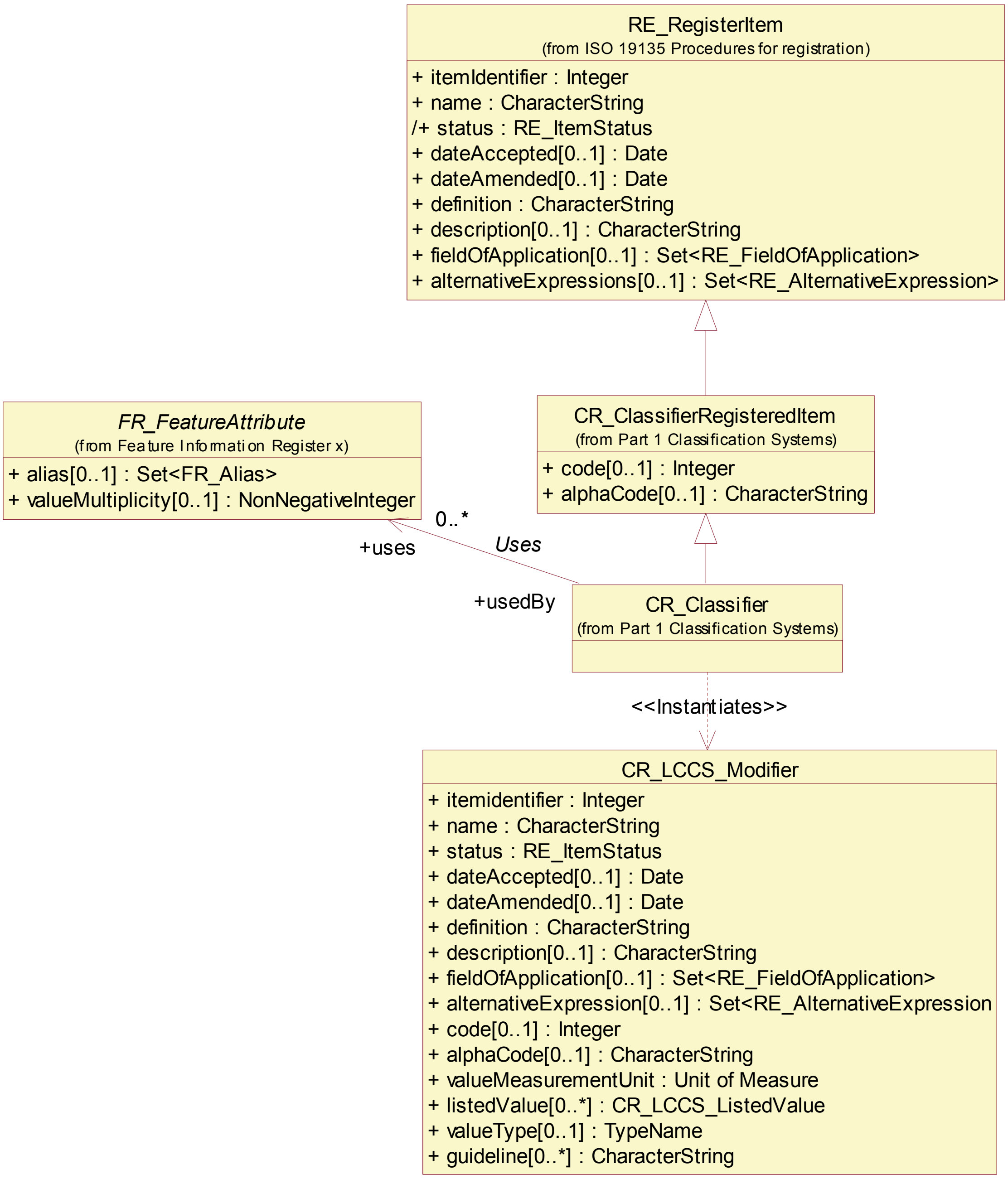

Figure 8 - Modifier Registered Item

8.2.4.3 Listed Values Item

This registered item describes the listed values that may be used with a classifier or a modifier. Listed Values are elements of a list and have a code, a name and a definition. Optionally the listed value may include a reference units of measure that may apply.

Figure 9 - Listed Value Registered Item

8.2.4.4 Units of Measure Item

This registered item describes units of measure that may be used with a classifier or a modifier or listed value. units of measure have a definition of a measure specification. Other attributes such as code and an alpha code may also be applied.

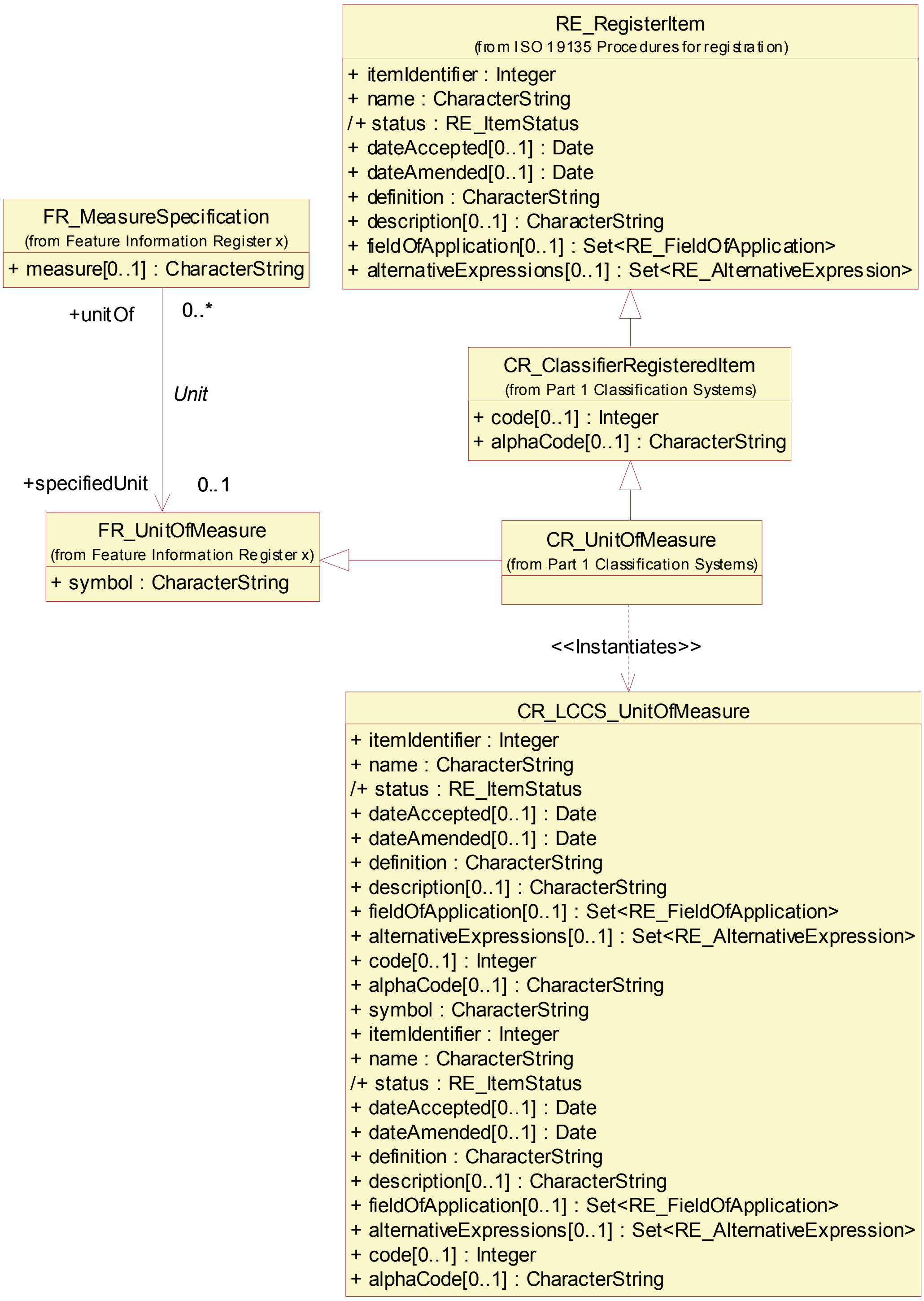

Figure 10- Units of Measure Registered Item

8.2.4.5 ClassificationRules Item

This registered item describes the rules that may be used to relate classifiers. These rules consist of code described in a machine readable form such as a programming language. The attribute "ruleLanguage" describes the language used to express the rules, including information such as the version of the language.

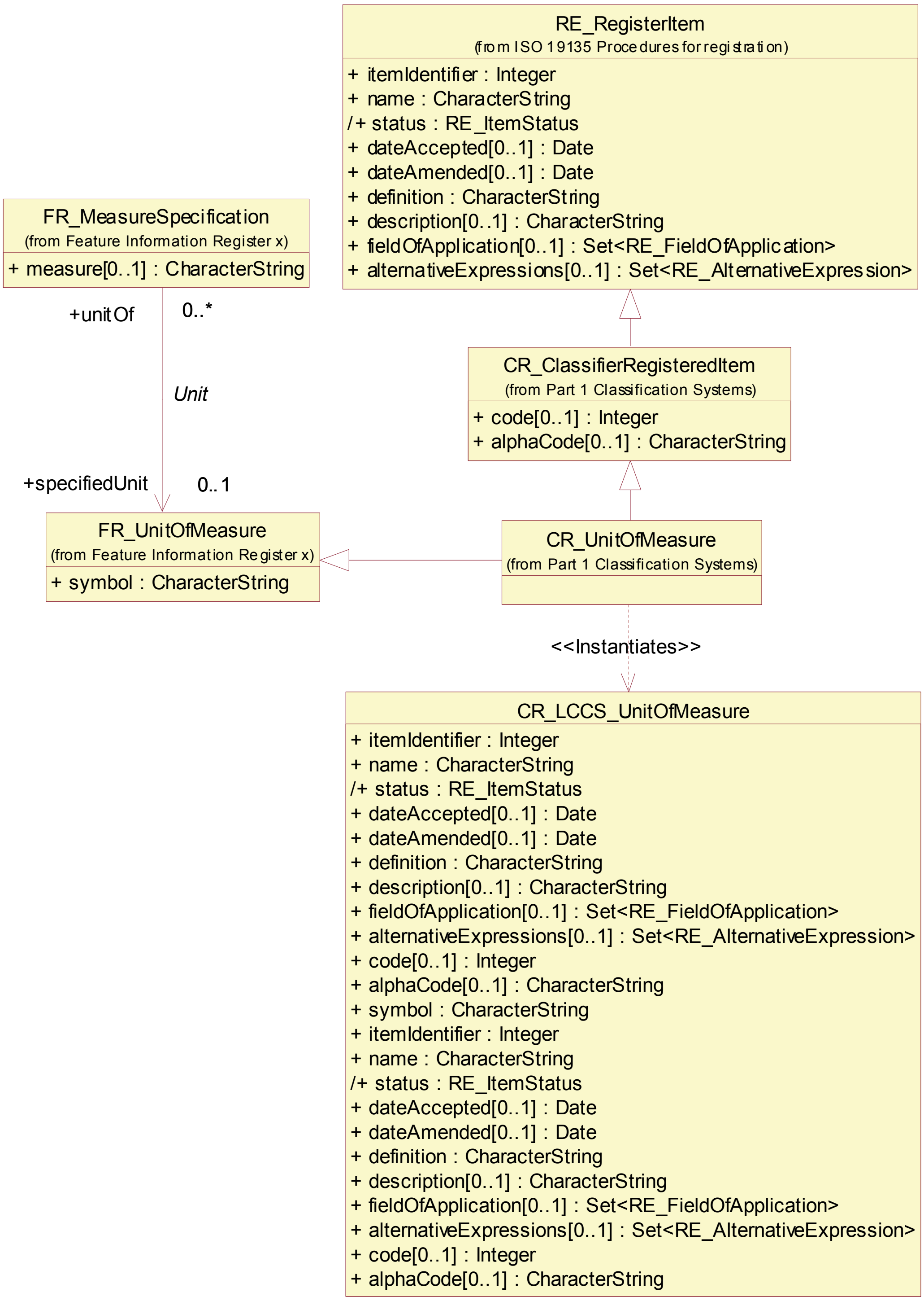

Figure 11 - Listed Value Registered Item

8.2.5

Annex A
(normative)

Abstract test suite

A.1 Introduction

This normative annex presents the abstract test suite for evaluating conformance to this International Standard. The abstract test suite contains a test module for a Classification System (A.2), and a test module for a register of classifiers (A.3).

A.2 Conformance of a classification system

A.2.1 LCCS coverage classification system

a) Test Purpose: Verify that an application schema or profile using the LCCS classification system satisfies the requirements that it instantiates CV_DiscreteCoverage.

b) Test Method: Inspect the documentation of the application schema or profile.

c) Reference: ISO 191xx-1 clause 5.

d) Test Type: Capability.

A.2.2 Constraint on classifiers in LCCS classification system

a) Test Purpose: Verify that an application schema or profile constrains classifiers, modifiers, listed values and units of measure to those established as part of the LCCS classification system

b) Test Method: Inspect the set of elements to ensure that they correspond to those registered in the LCCS register.

c) Reference: ISO 191xx-1 clause 5.5 and clause 6.2of this standard.

d) Test Type: Capability.

A.3 Conformance of a register of classifiers

A.3.1 Register content

a. Test Purpose: Verify that the items in the register contain the minimum specified content.

b. Test Method: Inspect each of a sample of entries in the register to ensure that they include all elements of information required by this International Standard.

c. Reference: Clause 6 and Clause 7.2

d. Test type: Capability

A.3.2 Test case for uniqueness of codes and alphaCodes

a. Test purpose: Verify the uniqueness of item *code* and *alphaCode* values used within the register for classifiers and modifiers.

b. Test method: For each item class in the register, check each item; no *code* or *alphaCode* shall appear more than once where the item *status* is “valid” (2).

c. Reference: Clause 8.1

d. Test type: Capability

A.3.3 Test case for compliance with the Rules language

e. Test purpose: Verify that the rules relating classifiers are compliant and valid code within the context of the language used to describe the rules.

f. Test method: For each item in the rules register, check each item; to determine that the rule is validly expressed in the language for expressing rules and is consistant with other rules.

g. Reference: Clause 7.1

h. Test type: Capability

Annex B
(informative)

Overview of Environmental Attributes of Each Major Land Cover Type of the LCCS Classification System

The following table presents an overview of each of the major land cover types of the LCCS system. This table is for illustrative purposes only. The reference source for information about the specific classifiers is the register of classifiers for the LCCS maintained by the Food and Agriculture Organization of the United Nations. This appendix corresponds to Appendix C of the UN FAO LCCS Classification concepts and user manual version 2, Ref [27].

Primarily Vegetated

A11 - CULTIVATED & MANAGED LANDS	
I. A. Life Form of the Main Crop	**code**
Trees	A1
Broadleaved	A7
Needleleaved	A8
Evergreen	A9
Deciduous	A10
Shrubs	A2
Broadleaved	A7
Needleleaved	A8
Evergreen	A9
Deciduous	A10
Herbaceous	A3
Graminoids	A4
Non-Graminoids	A5
Urban Vegetated Area(s)	A6
Parks	A11
Parkland	A12
Lawns	A13
B. Spatial Aspect - Size	
Large-to Medium-Sized Field(s)	B1
Large-Sized Field(s)	B3
Medium-Sized Field(s)	B4
Small-Sized Field(s)	B2
B. Spatial Aspect - Distribution	
Continuous	B5
Scatterred Clustered	B6
Scattered Isolated	B7
II. C. Crop Combination	
Single Crop	C1
Multiple Crop	C2
One Additional Crop	C3
Trees	C5
Shrubs	C6
Herbaceous Terrestrial	C7
Herbaceous Aquatic	C8
Simultaneous	C17
Overlapping	C18
Sequential	C19
Trees	C13
Shrubs	C14
Graminoids	C15
Non-graminoids	C16
Simulltaneous	C17
Overlapping	C18
Sequential	C19
III. D. Cultural Practices - Water Supply	
Rainfed	D1
Post-flooding	D2
Irrigated	D3
Surface Irrigation	D4
Sprinkler Irrigation	D5
Drip Irrigation	D6
D. Cult. Practices - Cult. Time Factor	
Shifting Cultivcation	D7
Fallow System	D8
Permanent Cultivation	D9
S. Crop Type	
Food Crops	S1
Cereals (& Pseudocereals)	S3
Roots & Tubers	S4
Pulses & Vegetables	S5
Fruit & Nuts	S6
Fodder Crops	S7

A12 - NAT. & SEMI-NAT. TERRESTRIAL VEG.	
I. A Life Form of the Main Strata	**Code**
Woody	A1
Trees	A3
Shrubs	A4
Herbaceous	A2
Forbs	A5
Graminoids	A6
Lichens/ Mosses	A7
Lichens	A7
Mosses	A9
A. Cover	
Closed (> 70-60%)	A10
Open (70-60 - 20-10%)	A11
. (70-60 - 40%)	A12
. (40-20 - 10%)	A13
Closed to Open (100 -15%)	A20
. (100-40%)	A21
Sparse (20-10 - 1%)	A14
. (<20-10 - 4%)	A15
. Scattered (4-1%)	A16
B. Height	
7-2 m (for Woody)	B1
>30-3 m (for Trees)	B2
. >14 m	B5
. 14-7 m	B6
. 7-3	B7
5-0.3 m	B3
. 5-0.5 m	B14
. 5-2 m	B8
. 2-0.5 m	B9
. <0.5 m	B10
3-0.03 m	B4
3-0.3 m	B15
3-0.8 m	B11
0.8-0.3 m	B12
0.3-0.03 m	B13
C. Spatial Distribution/Macropattern	
Continuous	C1
Fragmented	C2
Striped	C4
Cellular	C5
Parklike Patches	C3
II. D. Leaf Type	
Broadleaved	D1
Needleleaved	D2
Aphyllous	D3
E. Leaf phenology	
Evergreen	E1
Semi-Evergreen E4	
Deciduous	E2
Semi-Deciduous	E4
Mixed	E3
Mixed (for Forbs/Graminoids)	E5
Annual	E6
Perennial	E7
III. F. Stratification - Second Layer	
Second Layer Absent	F1
Second Layer Present	F2
Woody	F3
Trees	F4
Shrubs	F5
Herbaceous	F4

A24 - NAT. & SEMI-NAT. AQUATIC VEG.	
I . A. Life Form of the Main Strata	**Code**
Woody	A1
Trees	A3
Shrubs	A4
Herbaceous	A2
Forbs	A5
Rooted	A8
Free Floating	A9
Graminoids	A6
Lichens/Mosses	A7
Lichens	A10
Mosses	A11
A. Cover	
Closed (> 70-60%)	A12
Open (70-60 - 20-10%)	A13
Closed to Open (100-15%)	A20
(100-40%)	A21
(70-60 - 40%)	A12
(40-20 - 10%)	A15
Sparse (20-10 - 1%)	A16
(<20-10 - 4%)	A17
Scattered (4-1%)	A18
B. Height	
7-2 m (for Woody)	B1
>30-3 m (for Trees)	B2
>14 m	B5
14-7 m	B6
7-3 m	B7
5-0.3 m	B3
5-0.5 m	B14
5-2 m	B8
2-0.5 m	B9
<0.5 m	B10
3 - 0.03 m	B4
3 - 0.3 m	B15
3-0.8 m	B11
0.8-0.3 m	B12
0.3-0.03 m	B13
II. C. Water Seasonality	
More Than Three Months A Year	C1
Persistent for Whole Day	C4
With Daily Variations	C5
Less Than Three Months A Year	C2
Waterlogged	C3
III. D. Leaf Type	
Broadleaved	D1
Needleleaved	D2
Aphyllous	D3
E. Leaf Phenology	
Evergreen	E1
Semi-Evergreen	E3
Deciduous	E2
Semi-Deciduous	E3
Mixed	E4
Mixed (for Forbs/Graminoids)	E5
Annual	E6
Perennial	E7
IV. F. Stratification - Second Layer	
Second Layer Absent	F1
Second Layer Present	F2
Woody	F3
Trees	F4
Shrubs	F5

Primarily Non-Vegetated

B15 - ARTIFICIAL SURFACES AND ASS. AREAS	
I. A. Surface Aspect	**Code**
Built Up	A1
Linear	A3
Roads	A7
Paved	A8
Unpaved	A9
Railways	A10
Comm. Lines/Pipelines	A11
Non-Linear	A4
Industrial a/o Other	A12
High density	A14
Medium Density	A15
Low Density	A16
Scattered density	A17
Urban Areas	A13
High density	A14
Medium Density	A15
Low Density	A16
Non Built Up	A2
Waste Dump Deposit	A5
Extraction Sites	A6
A. Built-Up Object	
(scroll list with pre-defined objects)	
B16 - BARE AREAS	
I. A. Surface aspects	**Code**
Consolidated	A1
Bare Rock a/o Coarse Frgm.	A3
Bare Rock	A7
Gravel/Stones/Boulders	A8
Gravel	A14
Stones	A15
Boulders	A16
Hardpans	A4
Ironpan/Laterite	A9
Petrocalcic	A10
Petrogypsic	A11
Unconsolidated	A2
Bare Soil a/o Other Uncon. Mat.	A5
Stony (5 - 40%)	A12
Very Stony (40 - 80%)	A13
Loose and Shifting Sands	A6
Stony (5 - 40%)	A12
Very Stony (40 - 80%)	A13
II. B. Macropattern - Sands	
Dunes	B1
Barchans	B2
Saturated	B5
Unsaturated	B8
Parabolic Dunes	B3
Saturated	B6
Unsaturated	B9
Longitudinal Dunes	B4
Saturated	B7
Unsaturated	B10
Salt Flat	B13
B. Macropattern - Soils	
Gilgai	B11
Termite Mounds	B12
B27 - ARTIFICIAL WATERBODIES	
I. A. Physical Status	**Code**
Water	A1
Flowing	A4

Beverages & Stimulants S8
Other S13
Non-Food Crops S2
Industrial Crops S9
Wood/Timber S10
Other S14

A23 - CULTIVATED AQUATIC AREAS
I. A. Life Form of the Main Crop **Code**
Graminoids A1
Non-Graminoids A2
Woody A3

B. Spatial Aspect - Size
Large-To Medium-Sized Field(s) B1
Large-Sized Field(s) B3
Medium-Sized Field(s) B4
S mall-Sized Field(s) B2

B. Spatial Distribution
Continuous B5
Scattered Clustered B6
Scattered Isolated B7

II. C. Water Seasonality
Persistent for Whole Day C1
With Daily Variations C2
Waterlogged C3

III. D. Cultural Practices - Fallow period
Permanent D1
Relay Intercropping D2
Sequential D3

S. CROP TYPE
Food Crops S1
Cereals S3
Fodder Crops S7
Other S13
Non-Food Crops S2
Crops for Biological Filtration S11
Fibre Crops & Structural Mat. S12
Other S14

G Cover - Second Layer
Closed To Open F7
Closed (> 70-60%) F8
Open (70-60 - 20-10%) F9
Sparse (20-10 - 1%) F10

H. Height - Second Layer
7-2 m (for Woody) G1
>30-3 m G2
>14 m G5
14-7 m G6
7-3 m G7
5 - 0.3 m G3
5-2 m G8
2-0.5 m G9
< 0.5 m G10
3 - 0.03 m G4
3-0.3 m G11
0.3-0.03 m G12

F. Stratification - Third Layer
Third Layer Absent F1
Third Layer Present F2
Woody F3
Trees F4
Shrubs F5
Herbaceous F4

G. Cover - Third Layer
Closed To Open F7
Closed (> 70-60%) F8
Open (70-60 - 20-10%) F9
Sparse (20-10 - 5%) F10

H. Height - Third Layer
7-2 m (for Woody) G1
>30-3 m G2
>14 m G5
14-7 m G6
7-3 m G7
5 - 0.3 m G3
5-2 m G8
2-0.5 m G9
< 0.5 m G10
3 - 0.03 m G4
3-0.3 m G11
0.3-0.03 m G12

T. FLORISTIC ASPECT
Single Plant Species T1
Dominant Species T3
Most Frequent Species T4
Groups of Plant Species T2
Statistically Derived Groups T5
Non-Statistically Derived T6

Herbaceous F4

G. Cover - Second Layer
Closed To Open F7
Closed (> 70-60%) F8
Open (70-60 - 20-10%) F9
Sparse (20-10 - 1%) F10

H. Height - Second Layer
7 - 2 m (for Woody) G1
>30 - 3 m G2
>14 m G5
14-7 m G6
7-3 m G7
5 - 0.3 m G3
5-2 m G8
2-0.5 m G9
< 0.5 m G10
3 - 0.03 m G4
3-0.3 m G11
0.3-0.03 m G12

T. Floristic Aspect
Single Plant Species T1
Dominant Species T3
Most Frequent Species T4
Groups of Plant Species T2
Statistically Derived Groups T5
Non-Statistically Derived T6

Standing A5
Snow A2
Ice A3
Moving A6
Stationary A7

B. Persistence
Perennial (> 9 Months) B1
9-7 (months) B7
6-4 (months) B8
3-1 (months) B9
Non-Perennial (< 9 Months) B2
Surface Aspect: Bare Rock B4
Surface Aspect: Bare Soil B5
Surface Aspect: Sand B6
Tidal Area B3
Surface Aspect: Bare Rock B4
Surface Aspect: Bare Soil B5
Surface Aspect: Sand B6

II. C Depth
Deep to Medium C1
Shallow C2

D Sediment Load
Almost No Sediment D1
With Sediment D2

V. SALINITY
Fresh (<1 000 ppm of TDS) V1
Slightly Saline V2
Moderately Saline V3
Very Brine V4
Brine V5

B28 INLAND WATERBODIES, SNOW & ICE
I. Physical Status Code
Water A1
Flowing A4
Standing A5
Snow A2
Ice A3
Moving A6
Stationary A7

B. Persistence
Perennial (> 9 Months) B1
9-7 (months) B7
6-4 (months) B8
3-1 (months) B9
Non-Perennial (< 9 Months) B2
Surface Aspect: Bare Rock B4
Surface Aspect: Bare Soil B5
Surface Aspect: Sand B6
Tidal Area B3
Surface Aspect: Bare Rock B4
Surface Aspect: Bare Soil B5
Surface Aspect: Sand B6

II. C Depth
Deep to Medium C1
Shallow C2

D. Sediment Load
Almost No Sediment D1
With Sediment D2

V. SALINITY
Fresh (<1 000 ppm of TDS) V1
Slightly Saline V2
Moderately Saline V3
Very Brine V4
Brine V5

Environmental Attributes for Each

A11: Landform, Lithology, Soil, Climate, Altitude, Erosion and Crop Cover.
A12: Landform, Lithology, Soil, Climate, Altitude and Erosion.
A23: Landform, Lithology, Soil, Climate, Altitude, Erosion and Crop Cover.
A24: Landform, Lithology, Soil, Climate, Altitude and Salinity.
B15: Landform, Climate and Altitude.
B16: Landform, Climate, Altitude, Vegetation and Erosion.
B27/B28: Climate and Altitude.

E N V I R O N M E N T A L A T T R I B U T E S

L. LANDFORM* **Code**
Level Land L1
Sloping Land L2
Steep Land L3

Quartzararenite M224
Litihic arenite M225
Feldspathice arenite/arkose M226
Graywacke M227

Tertiary M500
Piocene M510
Miocene M520
Oligocene M530

P. ALTITUDE* Code
< 50 - 300 m P1
< 50 m P5
50 - 100 m P6

Land With Composite Landforms	L4
M. LITHOLOGY*	**Code**
Igneous rock	M100
Igneous plutonic rock	M110
Granite	M111
Granodiorite	M112
Quartz diorite	M113
Syenite	M114
Monzonite	M115
Diorite	M116
Gabbro	M117
Foidic plutonic rock	M118
Ultramatic plutonic rock	M119
Igneous hypabyssal rock	M120
Aplite	M121
Pegmatite	M122
Porphyry	M123
Dolerite/diabase	M124
Igneous volcanic rock	M130
Rhyolite	M131
Dacite	M132
Trachyte	M133
Latite	M134
Andesite	M135
Basalt	M136
Phonolite	M137
Tephrite	M138
Pyroclastic rock	M140
Ash	M141
Lapilli	M142
Scoria	M143
Tuff	M144
Ignimbrite	M145
Lahar	M146
Agglomerate	M147
Other Igneous rock	M199
Sedimentary rock	M200
Unconsolidated clastic sed. Rock	M210
Clay	M211
Silt	M212
Sand	M213
Gravel	M214
Loess	M215
Loam	M216
Colluvium	M217
Shells	M218
Cons. clastic siliceous sed. Rock	M220
Mudstone	M221
Siltstone	M222
Shale	M223
Conglomerate	M228
Breccia	M229
Calcareous rock	M230
Marl	M231
Calcilutite	M232
Calcarenite	M233
Calcirudite	M234
Algal/reefal limestone	M235
Travertine	M236
Tufa	M237
Dolomite	M238
Evaporite	M240
Gypsum	M241
Halite	M242
Organic rock	M250
Peat	M251
Lignite	M252
Coal	M253
Tar	M254
Residual rock	M260
Laterite	M261
Bauxite	M262
Kaolin	M263
Other Sedimentary rock	M299
Metamorphic rock	M300
Contact metamorphic rock	M310
Hornfels	M311
Spotted slate	M312
Skarn	M313
Cataclastic metamorphic rock	M320
Cataclastic breccia	M321
Mylonite	M322
Regional-metamorphic rock	M330
Slate	M331
Schist	M332
Gneiss	M333
Migmatite	M334
Granulite	M335
Eclogite	M336
Quartzite	M337
Marble	M338
Other metamorphic rock	M399
M. LITHOLOGY - AGE GEOL PARENT MAT	
Quartenary	M400
Holocene	M410
Pleistocene	M420
Late Pleistocene	M421
Middle Pleistocene	M422
Early Pleistocene	M423
Eocene	M540
Paleocene	M550
Mesozoic	M600
Cretaceous	M610
Jurassic	M620
Triassic	M630
Paleozoic	M700
Permian	M710
Carboniferous	M720
Devonian	M730
Silurian	M740
Ordovician	M750
Cambrian	M760
Precambrian	M800
N. SOIL - SURFACE ASPECT	**Code**
Bare Rock	N1
Soil Surface	N2
Stony (5 - 40%)	N5
Very Stony (40 - 80%)	N6
Loose and Shifting Sands	N3
Stony (5 - 40%)	N5
With Dunes	N7
Hardpans	N4
Ironpan/Laterite	N8
(petro)Calcic	N9
PetroGypsic	N10
Hardened Plinthite	N11
N. SOIL - SUBSURFACE ASPECT	
FAO's Major Soil Groups*	N12
O. CLIMATE*	**Code**
Thermal Climate:	
Tropics	O1
Subtropics - Summer rainfall	O2
Subtropics - Winter Rainfall	O3
Temperate Oceanic	O4
Temperate Continental	O5
Boreal Oceanic	O6
Boreal Continental	O7
Polar Arctic	O8
Moisture Determined LGP:	
Hyperarid	O9
Arid	O10
Dry Semi-Arid	O11
Moisture Semi-Arid	O12
Subhumid	O13
Humid	O14
Perhumid	O15
100 - 300 m	P7
300 - 1500 m	P2
300 - 600 m	P8
600 - 1000 m	P9
1000 - 1500 m	P10
1500 - 3000 m	P3
1500 - 2000 m	P11
2000 - 2500 m	P12
2500 - 3000 m	P13
3000 - > 5000 m	P4
3000 - 3500 m	P14
3500 - 5000 m	P15
> 5000 m	P16
Q. EROSION	
No Visible Erosion	Q1
Visible Evidence of Erosion	Q2
Water Erosion	Q3
Sheet	Q6
Rill	Q7
Gully	Q8
Wind Erosion	Q4
Mass Movement	Q5
R. WATER QUALITY	
Fresh Water	R1
Brackish Water	R2
Saline Water	R3
U. VEGETATION	
Scattered Vegetation Present	U1
Woody	U2
Herbaceous	U3
Forbs	U5
Graminoids	U6
Lichens/Mosses	U4
Lichens	U7
Mosses	U8
W. CROP COVER/DENSITY	
Permanent Life Forms:	
Closed Cover > (70-60%)	W1
Closed Cover (70-60) - (20-10)%	W2
Sparse Cover <(20-10)%	W3
Temporary Life Forms:	
High Crop Density (> 60%)	W4
Medium Crop Density (60 - 30%)	W5
Low Crop Density (30 - 15%)	W6

REFERENCES: **Landform**: UNEP/ISSS/ISRIC/FAO, 1995. - **Lithology**: provided by S. B. Kroonenberg, 1998. - **Climate**: De Pauw, Nachtergaele and Antoine, 1996. - **Soils**: FAO/Unesco/ISRIC, 1990; FAO, 1993

Bibliography

[1] Alexandratos, N. (ed). 1995. *World Agriculture: Towards 201*0. An FAO Study. Rome: FAO, and Chichester, UK: Wiley and Sons.

[2] Anderson, J.R., Hardy, E.E., Roach, J.T. & Witmer, R.E. 1976*. A land use and land cover classification system for use with remote sensor data*. U.S. Geological Survey

[3] Professional Paper, No. 964. USGS, Washington, D.C.

[4] Barisano, E. 1996. *Proposition préliminaire pour une légende de l'occupation du sol pour le projet Africover. Draft report*. FAO, Rome.

[5] Beek, K.J., De Bie, K. & Driessen, P. 1997*. Land information and land evaluation for land use planning and sustainable land management. The Land*, 1(1): 27–44.

[6] Belward, A. (ed). 1996. *The IGBP-DIS global 1 km land cover data set "DISCover" Proposal and implementation plans. Report of the Land Cover Working Group of the IGBP-DIS*. IGBP-DIS Working Paper, No. 13. Stockholm.

[7] CEC [Commission of the European Communities]. 1993. *CORINE Land Cover – Guide technique*. Brussels.

[8] Clocksin, W.F., Mellish, C.S., 1987, *Programming in Prolog*, Springer-Verlag, NewYork USA, ISBN: 0-387-17539-3

[9] Cowardin, L.M., Carter, V., Golet, F.C. & LaRoe, E.T. 1979. *Classification of wetlands and deepwater habitats of the United States. Office of Biological Services,Fish and Wildlife Services*, U.S. Department of the Interior, Washington D.C.

[10] Danserau, P. 1961. *Essai de répresentation cartographique des éléments structuraux de la végétation. pp. 233–255, in: H. Gaussen (ed). Méthodes de la cartographie de la végétation*. Centre National de la Recherche Scientifique. 97th International Colloquium, Toulouse, France, 1960.

[11] Darwin, R., Tsigas, M., Lewandrowski, J. & Raneses, A. 1996*. Land use and cover in ecological economics. Ecological Economics*, 17: 157–181.

[12] De Pauw E., Nachtergaele F.O. & Antoine J. 1996*. A provisional world climatic resource inventory based on the length-of-growing-period concept*. In Batjes N.H.,

[13] Kauffman J.H. & Spaargaren O.C.(Ed.), *National Soil Reference Collections and Databases* (NASREC – Vol.3), ISRIC, 1996, pp.30-43.

[14] Di Gregorio, A. 1991. *Technical report on the land cover mapping of Lebanon*. FAO Project NECP/LEB/001/SAU.

[15] Di Gregorio, A. 1995. *FAO land use statistics: A case study for three countries using remote sensing and GIS technology.* Consultancy Report for FAO Statistics Division, Rome.

[16] Di Gregorio, A. & Jansen, L.J.M. 1997. *A new concept for a land cover classification system. Proceedings of the Earth Observation and Environmental Information* 1997 Conference. Alexandria, Egypt, 13–16 October 1997.

[17] Di Gregorio, A. & Jansen, L.J.M. 1996a. *Part I – Technical document on the Africover Land Cover Classification Scheme*. pp. 4–33; 63–76, in: FAO. Africover Land Cover Classification. 1997.

[18] Di Gregorio, A. & Jansen, L.J.M. 1996b. *FAO Land Cover Classification System: A Dichotomous, Modular-Hierarchical Approach.* Paper presented at the Federal Geographic Data Committee Meeting – Vegetation Subcommittee and Earth Cover Working Group. Washington D.C., 15–17 October 1996.

[19] Di Gregorio, A. & Jansen, L.J.M. 1996c*. The Africover Land Cover Classification System: A Dichotomous, Modular-Hierarchical Approach.* Working Paper with the Proposal for the International Working Group Meeting. Dakar, 29–31 July 1996. FAO, Rome.

[20] Duhamel, C. 1995. *Programme télédétection et statistique. Cadre de travail statistique utilisation des sols*. Draft. Eurostat/CESD-Communautaire, Luxembourg.

[21] Eiten, G. 1968. *Vegetation forms. A classification of stands of vegetation based on structure, growth form of the components, and vegetative periodicity*. Boletim do Instituto de Botanica (San Paulo), No. 4.

[22] European Soils Bureau (ed). 1997. *Geo-referenced Soil Database For Europe. Manual of Procedures*. Draft 2.1. pp. 79–81.

[23] FAO. 1988. FAO-UNESCO *Soil Map of the World. Revised Legend*. FAO/UNESCO/ISRIC World Soil Resources Reports, No. 60 (Reprinted 1990)

[24] FAO. 1995. *Planning for sustainable use of land resources. Towards a new approa*ch. FAO Land and Water Bulletin, No. 2.

[25] FAO. 1997. *Africover Land Cover Classification*. Rome.

[26] FAO. 2000. *Land Cover Classification System (LCCS). Classification concepts and user manual for software version 1.0*. By A. Di Gregorio and L.J.M. Jansen. Rome, , ISBN 92-5-104216-0.

[27] FAO. 2005, *LCCS - Land Cover Classification System - Classification concepts and user manual,* Version 2, By A. Di Gregorio, Rome, 2005, ISBN 92-5-105327-8

[28] Ford-Robertson, F.C. (ed). 1971. *Terminology of Forest Science, Technology Practice and Products*. Society of American Foresters, Washington, DC.

[29] Fosberg, F.R. 1961. *A classification of vegetation for general purposes*. Tropical Ecology, 2: 1–28.

[30] Humboldt, A. von. 1807. *Ideen zu einer Physiognomik der Gewaechse*. Tübingen.

[31] Jansen, L.J.M. & Di Gregorio, A. 1997. *Problems of current classifications: development of a new approach*. Paper prepared for the EC Eurostat Seminar on Land Cover and Land Use Information Systems for European Policy Needs. Luxembourg, 21–23 January 1998.

[32] Kuechler, A.W. & Zonneveld, I.S. (eds). 1988. *Vegetation Mapping. Handbook of Vegetation Science*, Vol. 10. Dordecht, the Netherlands: Kluwer Academic.

[33] Meyer, W.B. & Turner II, B.L. 1992. *Human population growth and global land use/land cover change*. pp. 39–61, in: Annual Review of Ecology and Systematics, No. 23.

[34] Mueller-Dombois, D. & Ellenberg, J.H. 1974. *Aims and Methods of Vegetation Ecology*. New York, USA and London: John Wiley.

[35] Nègre, T. 1995. *Report of the Preparatory Mission: Outlines for the Africover Classification System*. Draft document. FAO, Rome.

[36] Reichert, P. & Di Gregorio, A. 1995*. Preparation of a forest cover map and reconnaissance forest inventory of Albania.* Technical Report of FAO Project GCP/ALB/002/IDA.

[37] SCS [U.S. Soil Conservation Service]. 1975. *Soil Taxonomy*, by the Soil Survey Staff. USDA Agriculture Handbook, No. 436. Washington, DC.

[38] Sims, D. 1995. *Background note on ongoing activities relating to land cover and land use classification*. FAO/AGLS, Rome.

[39] Sokal R. 1974. *Classification: purposes, principles, progress, prospects*. Science, 185(4157): 111–123.

[40] Thompson, M. 1996. *A standard land-cover classification for remote-sensing applications in South Africa*. South African Journal of Science, 92: 34–42.

[41] Townshend, J.R.G. (ed). 1992. *Improved global data for land applications*. IGBP Report No. 20. IGBP Secretariat/Royal Swedish Academy of Sciences, Stockholm.

[42] Trochain, J.L. 1961. *Représentation cartographique des types de végétation intertropicaux africains*. pp. 87–102, in: H. Gaussen (ed). Méthodes de la cartographie de la végétation. Centre National de la Recherche Scientifique. 97th International Colloquium, Toulouse, France, 1960.

[43] UNEP/FAO. 1994. *Report of the UNEP/FAO Expert Meeting on Harmonizing Land Cover and Land Use Classifications*. Geneva, 23–25 November 1993. GEMS Report Series, No. 25.

[44] UNEP/ISSS/ISRIC/FAO. 1995. *Global and National Soils and Terrain Digital Databases* (SOTER).Procedures Manual. FAO World Soil Resources Reports, 74 (Rev. 1).

[45] UNESCO. 1973. *International Classification and Mapping of Vegetation*. Paris.

[46] Walter, H. 1968–1973. *Die Vegetation der Erde*. Stuttgart, Germany: Gustav Fischer Verlag.

[47] White, F. 1983. *The Vegetation of Africa.* A Descriptive Memoir to Accompany the UNESCO/EATFAT/UNSO Vegetation Map of Africa. UNESCO. Paris, France.

[48] Wyatt, B., Billington, C., De Bie, K., De Leeuw, J., Greatorex-Davies, N. & Luxmoore, R.(unpubl.*) Guidelines for land cover and land use description and classification*. Draft FinalReport. UNEP/FAO/ITC/ITE/WCMC, Huntingdon, UK.

Related Documents

[49] FAO. 2000. *Africover: Specifications for geometry and cartography*, FAO Environment and Natural Resources Series. Rome.

[50] FAO. 2002. Terrestrial Carbon Observation: The Ottawa assessment of requirements, status and next steps, FAO Environment and Natural Resources Series. Rome.

[51] FAO. 2002. *Terrestrial Carbon Observation: The Rio de Janeiro recommendations for terrestrial and atmospheric measurements*, FAO Environment and Natural Resources Series. Rome.

[52] FAO. 2003. *Organic agriculture: Environment and food security*, FAO Environment and Natural Resources Series. Rome.

[53] FAO. 2002. Terrestrial Carbon Observation: The Frascati report on in situ carbon data and information, FAO Environment and Natural Resources Series. Rome.

[54] FAO. 2003. *The Clean Development Mechanism: Implications for energy and sustainable agriculture and rural development projects*, FAO Environment and Natural Resources Series. Rome.

[55] FAO. 2003. *The application of a spatial regression model to the analysis and mapping of poverty*, FAO Environment and Natural Resources Series. Rome.

[56] FAO. 2005. *Coastal GTOS. Strategic design and phase 1 implementation plan*, FAO Environment and Natural Resources Series. Rome.

[57] FAO. 2005. *Frost Protection: fundamentals, practice and economics- Volume I and II + CD*, FAO Environment and Natural Resources Series. Rome.